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Radian Corp, Austin, TX

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Impact of Point Source Control Strategies on NO_2 Levels

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Impact of Point Source Control Strategies on NO_2 Levels

by

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ABSTRACT

The report gives final results of a study of the effect of two point source NO_x control strategies in the Chicago Air Quality Control Region (AQCR): combustion modification and flue gas treatment. The study involved the dispersion modeling of essentially all point and area sources of NO_x in the AQCR. Gaussian type dispersion models were used for nonreactive pollutants. The model results were adjusted empirically for atmospheric conversion of NO to NO_2. Two averaging times were considered: annual, corresponding to the present National Ambient Air Quality Standard (NAAQS) for NO_2; and 1-hour, corresponding to the anticipated new short-term NAAQS for NO_2. Results of the annual modeling indicate that large point sources are not major contributors to annual average NO_2 levels. However, results of the short-term modeling indicate that large point sources can be important contributors to 1-hour average NO_2 levels under certain meteorological conditions. Therefore, the control of large point source emissions can result in significant improvements in short-term NO_2 air quality.

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Air Pollution	Air Pollution Control	13B
Nitrogen Oxides	Stationary Sources	07B
Combustion	Point Sources	21B
Flue Gases	Combustion Modification	
Dispersing	Flue Gas Treatment	07A,13H
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I. CONCLUSIONS

The contributions to ambient nitrogen dioxide (NO_2) concentrations by distinct source classes in Chicago were studied to assess the improvement in air quality which could be expected if nitrogen oxides (NO_x) emission controls were used on major point sources (>100 million Btu* heat input). A non-reactive Gaussian dispersion model was used for both annual and short-term (one hour) average predictions of NO_2. The conclusions given here are based on the assumption that a constant NO_2/NO_x ratio can be applied uniformly to the predicted impacts of all sources. Annual average predictions assume an NO_2/NO_x ratio of one-half. Short-term predictions assume a ratio of one-quarter to one-half, depending on season of the year and hour of the day for worst case conditions. Measured NO_2 levels in Chicago were used to calibrate the annual average predictions, but short-term predictions could not be calibrated due to the lack of sufficient one hour average measurements.

Annual Average

While the major point sources account for nearly 40 percent of the total NO_x emissions in Chicago, they account for less than 10 percent of the ambient nitrogen dioxide (NO_2) levels, on the average. Considering major point source 'hot-spots', (i.e., localized areas of the city where major point source impact is the greatest) modeling results indicate that these sources account for 12 percent of a predicted NO_2 level of about 60 $\mu g/m^3$ or, equivalently, less than eight percent of the federal standard (100 $\mu g/m^3$). Taking a 'worst-case' approach and assuming that all NO_x emissions from major point sources are converted to NO_2, it was found that the predicted cumulative impact of all major point sources at locations of maximum annual impact is still only 15 percent of the standard.

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* Government policy is to stress the use of SI units in technical reports. However, for this report, commonly used units will be given. Conversion factors are shown in Appendix A.

It is concluded that total removal of large point source NO_x emissions would result in only a small improvement in annual average NO_2 air quality.

Short Term

Individual large point sources may account for 60 percent of a predicted one hour NO_2 concentration of 1100 $\mu g/m^3$ in industrial areas and 90 percent of a level of 800 $\mu g/m^3$ in non-industrial areas. This demonstrates that controlling large point sources may provide significant improvements in short-term NO_2 air quality. However, the degree of control required is highly dependent on the short-term ambient NO_2 standard adopted by EPA. The results summarized below show the percentage of the 14 largest existing point sources which would require controls for various standard levels if those standards were currently in effect.

Ambient Level ($\mu g/m^3$)	Percentage of Plants Requiring Combustion Modification	Flue Gas Treatment
1000	21	0
750	64	0
500	57	29
250	7	93

The percentages listed above are based on individual large point source impacts added to the impacts of other point sources, vehicular sources, and non-vehicular area sources. When large point sources are located near each other so that their impacts interact, the degree of control required increases significantly and more flue gas treatment is required.

Growth projections for NO_x emissions to 1985 do not demonstrate the need for additional point source controls above those shown above. There are two reasons for this unexpected result. First, the highest predicted short-term concentrations are dominated by large point sources to the extent that changes in the impacts from other sources do not make a large difference. Secondly, the change in impact of other sources by 1985 is small because increases in non-vehicular emissions are counterbalanced by the decrease in projected vehicular emissions.

It is concluded that control of large point source NO_x emissions would result in a significant improvement in short-term NO_2 air quality.

II. RECOMMENDATIONS

Further study of the application of NO_x control technology to large point sources should be undertaken. This is particularly important in light of the fact that the promulgation of a short-term ambient NO_2 standard will be forthcoming. Also, this study has shown that large point sources may dominate high short-term NO_2 levels, but these results are based upon a non-reactive plume model. More defensible results could be obtained if a model capable of treating reactive pollutants were employed. This would remove the necessity for the assumption of a fixed NO_2/NO_x ratio in the plume. The first step in this direction should be the use of a reactive plume model that simulates the conversion of NO to NO_2 in the plume. This type of model can be executed relatively inexpensively as compared to the costs associated with using a large scale photochemical model, but still yield valuable results that can be combined with the results of this study. Then, the next step should be to apply a large scale photochemical model to investigate the effect of alternative point source NO_x control strategies on not only NO_2 levels, but also the levels of other reactive species such as ozone on an AQCR basis.

Another area that should continue to be studied is the cost and performance characteristics of full-scale NO_x flue gas treatment (FGT) control devices. Current uncertainty in this area required simplifying assumptions to be made for this study in determining the degree and extent of control required.

III. INTRODUCTION

Nitrogen oxides (NO_x) may be formed during combustion of fossil fuels either by thermal fixation of atmospheric nitrogen from combustion air (thermal NO_x) or by conversion of fuel bound nitrogen to NO (fuel NO_x). The technques for controlling NO_x emissions from stationary sources are combustion modification (CM) and flue gas treatment (FGT). Combustion modification reduces the amount of NO_x formed while flue gas treatment removes the NO_x from the stack gases after it has been formed.

This document reports the results of a two-phase study to investigate these control strategies for the Chicago Air Quality Control Region (AQCR). The first phase of the study addresses the annual average ambient nitrogen dioxide (NO_2) levels, and the second phase addresses short-term ambient NO_2 levels.

Phase I

The Chicago AQCR was selected for use in this study because it was one of the five AQCR's in the nation that was classified Priority I by EPA, with respect to NO_2. A Priority I classification indicated that at least one measurement of NO_2 in the AQCR exceeded the annual average ambient standard. Other reasons for selecting the Chicago AQCR were that the National Emissions Data System (NEDS) data base for Chicago was reasonably complete, and that familiarity with the area had been gained through previous studies.

The original purpose of Phase I was to determine the effect on annual average ambient NO_x levels of applying NO_x control technology to large point sources in the AQCR. The dispersion model to be used to relate NO_x emissions to ambient concentrations was calibrated for Chicago. Due to a lack of ambient NO_x measurements in the area, it was necessary to calibrate the model for NO_2. Because of this, the purpose of this study was changed to focus on the effects of NO_x control technology on ambient NO_2 levels. This change greatly enhanced the usefulness of the study since NO_2 is the pollutant for which the ambient air standard is written.

Phase II

Near the end of the Phase I study it was learned that the establishment of a short-term standard for NO_2 was being seriously considered by Congress. Therefore, Phase II was undertaken to investigate the effect of CM and FGT control strategies for large point sources on short-term ambient concentrations for present and future years. This was done primarily because it is known that large point sources can have a high impact on short-term NO_x levels, even though they may have a relatively low impact on annual average levels.

Subsequent to the initiation of Phase II, Congress passed the 1977 Amendments to the Clean Air Act. One of the requirements of the 1977 Amendments is that EPA develop a short-term NO_2 standard, if it is found that sufficient health effects data exist upon which to base a standard. EPA is currently in the process of promulgating a short-term NO_2 standard. As of February, 1978, the levels being considered are 250, 500, 750, and 1,000 $\mu g/m^3$ based on a one-hour average. This study addresses these four levels.

The short-term impact assessment is made using Gaussian-type dispersion models. A significant part of the effort of this study was directed towards defining the short-term NO_x emission rates that should be used in the model. This was done by adjusting the annual average emission rates in the NEDS data base. Adjustments are made for season of the year, day of the week, time of day, etc. The entire emissions inventory for the Chicago AQCR, including vehicular and other area sources, was modeled using this approach.

The computer-predicted ambient NO_x concentrations are converted to ambient NO_2 concentrations by applying a ratio of NO_2 to NO_x determined from measured air quality data in Chicago. This ratio is a function of season of the year and time of day. The accuracy of this approach is not known, since several photochemical reactions are involved in the conversion of NO_x to NO_2. However, detailed modeling of the photochemistry is beyond the scope of this study. If future photochemical modeling indicates that different NO_2/NO_x ratios should be used, the results of this study can still be used by applying the new ratios.

The assessment of future year impacts required the estimation of growth in NO_x emissions. This was done for all sources except power plants using the U. S. Department of Commerce, Office of Business Economics and the U. S. Department of Agriculture, Economic Research Service (OBERS) projections for the future. The growth in power plant emissions is based on actual projections from the electric utilities in the AQCR.

It should be noted that this study focuses on the issue of what controls may be necessary to ensure point source compliance with a short-term NO_2 standard. To accomplish this goal the scenarios selected for study were chosen to determine the maximum air quality impact in the vicinity of large point sources. Other source types, such as vehicular sources, may also cause short-term standard violations in areas where there is little or no impact from large point sources or during meteorological conditions when point source impacts are minimal. However, these cases are beyond the scope of this study and are not addressed here.

IV. TECHNICAL DISCUSSION

A. Annual Average Impact

1. Basic Approach

The purpose of Phase I was to calibrate a Gaussian model for annual average NO_2 predictions for the Chicago AQCR and to use the results to address the effectiveness of various point source control strategies (CM or FGT), should they be implemented. Emission sources considered included large-point sources, other point sources, vehicular and other area sources. Emissions, meteorology and air quality monitoring data were obtained from readily available sources. Annual NO_2 predictions were made with an EPA model calibrated to NO_2 measurements, using an assumed NO_2/NO_x ratio (i.e., photochemistry was not modeled). Point source 'hot-spots' were studied to assess the maximum improvement in air quality which could be realized by controlling point sources.

2. Data Collection

This section will summarize the data collection procedures required in the annual average model calibration. Air quality, meteorological, point source, and area source data collections will be addressed separately.

a. Air Quality Monitoring Data

Actual NO_2 measurements at specific monitoring sites within Chicago were required to calibrate model predictions and establish correlation coefficients. Historical monitoring data for Chicago was obtained from the National Aerometric Data Bank (NADB), and this included all data reported to NADB through the first two quarters of 1975. Samples taken using the Jacobs-Hochheiser method were not considered since that method has been determined unacceptable by the EPA. After studying the sampling history of each site in terms of sampling frequency and consistency of data, it was decided that measurements made during 1974 represented the best available data.

NADB's air quality measurements for Chicago were supplemented by data obtained from the Cook County Department of Environmental Control and the city of Chicago Department of Environmental Control. These data, which were recorded in 1974, are the result of comprehensive, high quality assurance monitoring programs at the local level.

Monitoring locations were plotted on Chicago AQCR maps and analyzed with respect to suitability to the calibration effort. Sites located at or near the edge of the AQCR were removed from consideration due to the likelihood of significant impact from sources outside the AQCR at those sites. Including these sites in the calibration would have had an adverse effect on the overall correlation since only sources within the AQCR boundaries were modeled.

b. Meteorological Data

The Climatological Dispersion Model (CDM) requires annual average wind and stability conditions to be specified in terms of a stability wind rose, a trivariate frequency distribution of wind speed, wind direction, and stability class. The "stability" of the atmosphere refers to its ability to disperse pollutants. A "stability wind rose" shows the relationship between stability and wind direction. The Chicago wind rose for this study was generated from National Weather Service observations covering the 10-year period from 1959 to 1968. Other meteorological parameters required by the CDM are morning and afternoon average mixing heights and average temperatures which were taken from Holzworth. Mixing height is the thickness of a ground-based layer through which pollutant mixing and dispersion occurs.

c. Point Sources

Point source input parameters required by the CDM include stack height, stack diameter, stack gas exist velocity, exit temperature, annual average pollutant emission rate, and Universal Transverse Mercator (UTM) coordinates.

NO_x emissions data for point sources in Chicago were taken primarily from the NADB most current NEDS data base. Computerization at Radian facilitated the processing and editing of the information so that sources with missing parameters could be readily identified. For major point sources, state and local agencies were contacted to provide the missing data. Missing information for other point sources was estimated using national average parameters for sources of similar type, that is, having the same source classification code (SCC). National average parameter values, such as stack heights, temperature, and exit velocity, were computer-generated at Radian using magnetic tape listings of the entire NEDS point source data base.

After point source data for the AQCR had been edited on an individual source basis, summary printouts were compared to 1974 summary reports from the Illinois state agency to verify the overall agreement of the emission inventories. This effort identified some discrepancies, primarily in the breakdown by fuel type of electric utility emissions, and these were corrected to reflect the state's 1974 inventory.

d. Area Sources

Area source emissions are specified to the CDM in terms of a grid of squares where each square is assumed to have uniform pollutant emissions over its area. The way in which one arrives at this kind of input description for an entire AQCR, typically, is to gather area source emissions data at the county level and then devise a technique for apportioning the emissions throughout the grid of squares. The apportionment technique is described in Appendix B. The collection of county level emissions data will be addressed here.

Area source printouts for each county in the Chicago AQCR were obtained from NADB. Since vehicular emissions were to be apportioned separately from other area source emissions, the total NO_x emissions for each county had to be divided into vehicular and non-vehicular emissions. That information, however, is not given explicitly in the area source printouts because the data in each category is specified in terms of quantity of fuel burned, vehicle miles traveled, etc. Therefore, emission factors for each category were obtained from NADB and used to separate emissions accordingly. These emission factors are presented in Appendix C.

In Chicago, Radian was able to obtain vehicular emissions data directly from the Chicago Area Transportation Study (CATS). The CATS data were broken down into over 1700 traffic zones in an eight-county portion of the Chicago AQCR and provided estimates of nitric oxide (NO) emissions. The CATS data, being far superior to the county level data as far as apportionment was concerned, were used for vehicular emissions in the eight counties they covered (Cook, DuPage, Lake (Illinois), McHenry, Kane, Will, Lake (Indiana), Porter). NADB's data were used for vehicular emissions in the remainder of the Chicago AQCR as well as for non-vehicular emissions in the entire AQCR.

3. Modeling Approach

a. Model Calibration

The CDM was exercised with the point and area source emissions inventories for the Chicago AQCR to make predictions at selected monitoring points. Before a linear fit could be made for model predictions versus actual measurements, two items had to be addressed:

1) NO_2/NO_x adjustment factors, since the modeled emissions were in terms of NO_x, and

2) Background NO_2 concentrations, since the CDM predictions did not account for background.

NO_2/NO_x factors were sought for Chicago by studying measurements taken at monitoring stations reporting both NO and NO_2 concentrations. Although a few such monitors were identified in the Chicago region, there was not sufficient information to arrive at any conclusions. Radian, therefore, used 0.5 as an approximation for large United States cities in general. Documentation of this factor is provided in Appendix D.

It was also necessary to estimate a background NO_2 concentration for Chicago, since the CDM predictions did not include background. (For the purposes of the calibration effort, background was defined to be the ambient concentration resulting from any NO_x source outside the AQCR boundaries as well as natural sources within the AQCR.) Historical measurements taken by Radian in remote areas indicate levels between six and eighteen $\mu g/m^3$. A background of ten $\mu g/m^3$ was chosen for Chicago.

Actual calibration of the model was performed for Chicago in the following manner using NO_2 measurements and CDM predictions:

1. Multiply each model prediction by 0.5 (for NO_2/NO_x adjustment.

2. Subtract 10 $\mu g/m^3$ from each measured value (for background).

3. Perform least-squares fit to calculate s for the equation

$$y = sx$$

using the set of data points

$$(x_i, y_i), i = 1, 2, ---, N$$

where

x_i = adjusted CDM prediction at location of monitor i.
y_i = adjusted measured value at monitor i.
N = number of monitors used for calibration.

b. Annual Average Predictions

Calibrated CDM predictions were made for points within the isopleth map boundaries shown in Figure 1. The prediction at each point was divided into contributions from each of several different source classes. For point sources, the set of field

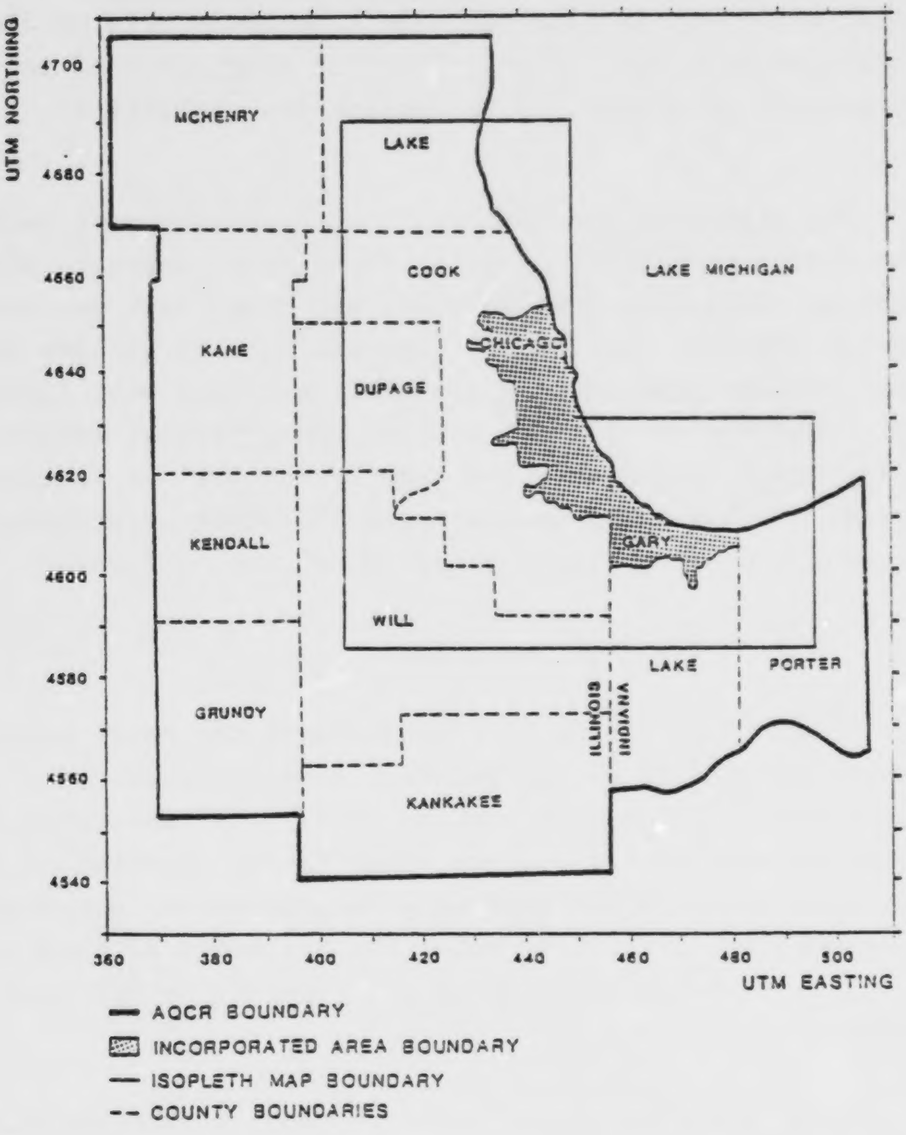


Figure 1. Chicago AQCR

points or 'receptors' formed a grid within the isopleth map boundary with a 2.5 Km spacing between points. Area source calculations were made using a 5.0 Km spacing. A coarse resolution was used for area sources for two reasons. First, area sources were apportioned to 5 x 5 Km squares. Significant additional information would not be expected from a receptor grid of finer resolution than five Km. Second, computer time required to model a receptor grid with 2.5 Km spacing was prohibitive.

NO_2 concentration isopleths were generated for each of four main source categories, namely, large point sources, other point sources, vehicular area sources, and other area sources. 'Large point sources' include all electric utility boilers and industrial boilers greater than 100 million Btu/hr heat input capacity. 'Other area sources' include non-vehicular mobile sources (aircraft, railroads, and vessels) as well as stationary area sources. A composite isopleth map including contributions from all source classes plus background was also generated.

c. 'Hot-Spot' Analysis

Specific locations in Chicago where the point source impact was predicted to be the greatest were selected for further analysis. These point source 'hot-spots' indicated the maximum improvement in air quality which can be expected on an annual average basis by controlling point soucre NO_x emissions. The improvement was quantified using the breakdown of predicted contributions by source class which was provided by the calibrated model.

Other specific locations of interest in the modeling regime were those points which exhibited the maximum overall NO_2 predictions from all source classes. These were locations where the air quality standard is most likely to be broken within the Chicago AQCR. Analyses at these critical points were also performed to quantify the potential air quality improvement resulting from point source NO_x controls.

4. Discussion of Results

a. Emissions and Meteorology

Table 1 presents a summary of the emission inventory (1974) used for Chicago. Table 2 gives a more detailed breakdown of point source emissions. The sources falling into the 'other' category in Table 2 were not modeled. Note that Tables 1 and 2 give emission rates in terms of NO_x.

TABLE 1. SUMMARY OF THE CHICAGO AQCR NO_x EMISSION INVENTORY

SOURCE CATEGORY	NO_x EMISSIONS (1974) tons/year	
Large point sources	259,473	(39%)
Other point sources	65,806	(10%)
Vehicular area sources	224,295	(33%)
Other area sources	124,248	(18%)
TOTAL	673,822	

Figure 2 presents the wind rose for Chicago which graphically depicts the meteorological wind data used in the CDM annual predictions. The morning and afternoon mixing heights used for annual predictions were 475 m and 1175 m, respectively. The average temperature was assumed to be 51°F (11°C).

TABLE 2. CHICAGO POINT SOURCE NO_x EMISSION SUMMARY

Class	Description	No. of Points	Emissions (T/YR)	Percent
1	Electric Utilities Coal	52	183947	56.55
2	Electric Utilities Oil	31	23602	7.26
3	Electric Utilities Gas	43	32080	9.86
4	Indus Coal (>100 MMBTU)	3	5400	1.66
5	Indus Oil (>100 MMBTU)	40	6712	2.06
6	Indus Gas (>100 MMBTU)	46	7732	2.38
7	Indus Coal (<100 MMBTU)	59	12900	3.97
8	Indus Oil (<100 MMBTU)	77	3314	1.02
9	Indus Gas (<100 MMBTU)	118	15899	4.89
10	Commer/Inst Boilers	27	1703	0.52
11	Industrial Processes	94	26682	8.20
12	Solid Waste	16	1564	0.48
	Other	367	3744	1.15
	Total	973	325279	100.00
	Total Modeled	606	321435	98.85

b. Calibration Results

Air quality measurements and monitor locations are shown in Figure 3. CDM predictions at these locations provided the data necessary to calibrate the annual model. Figure 4 shows the calibration data points and the least-squares line (forced through the origin) which yields the calibration equation:

$$y = 0.63\,x + B \qquad (1)$$

where

y = calibrated NO_2 predictions

x = modeled NO_2 prediction (=0.5 x NO_x)

B = background NO_2, assumed to be 10 $\mu g/m^3$.

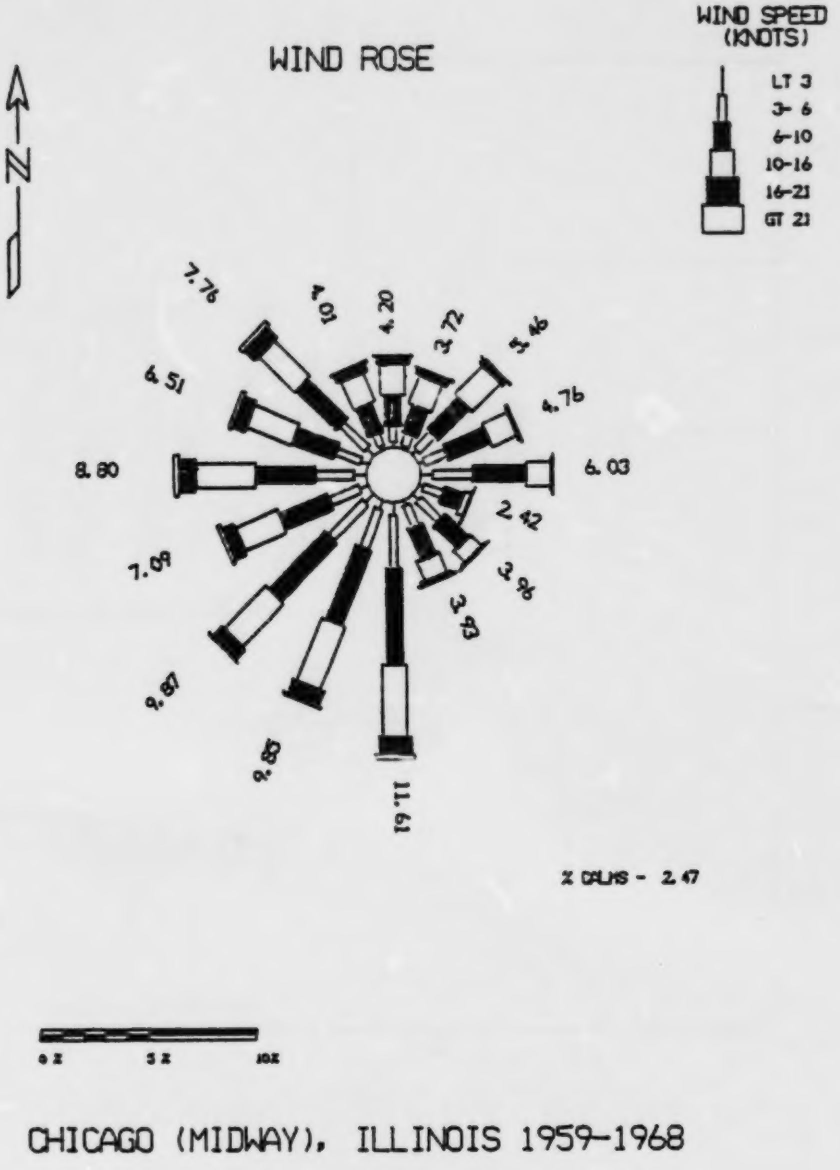
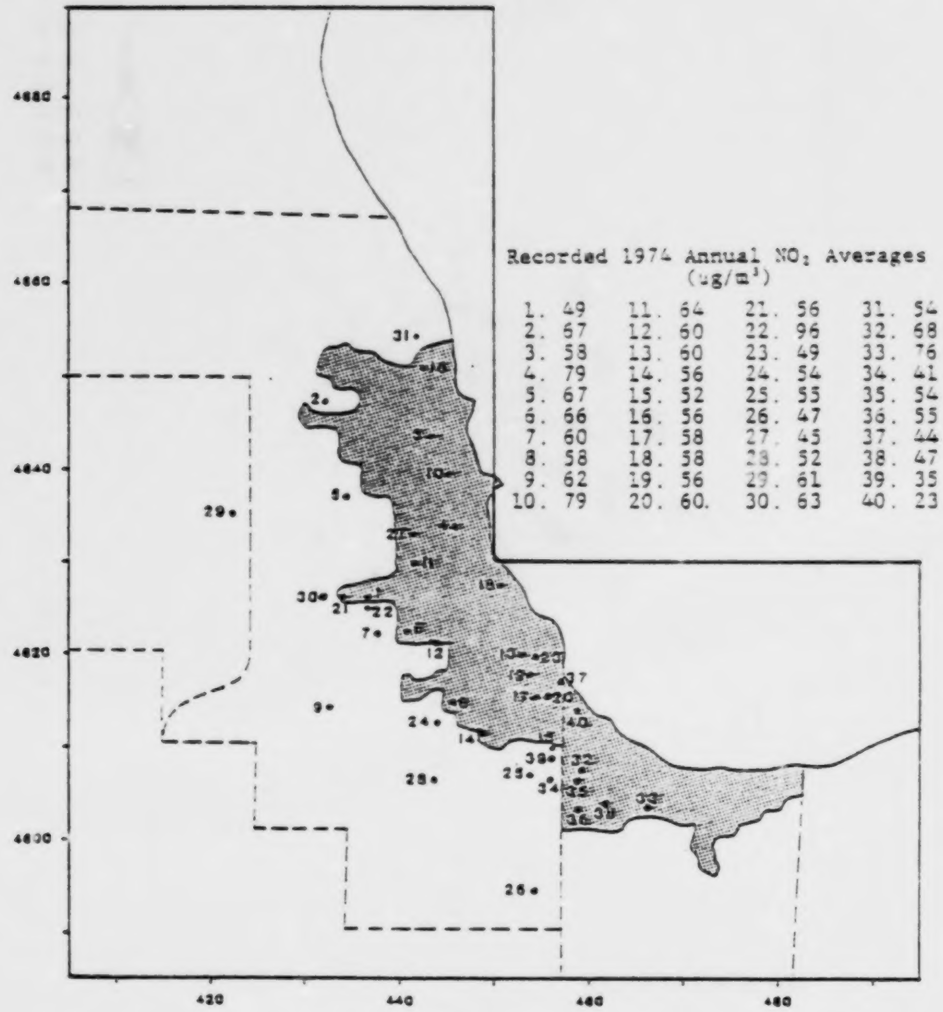


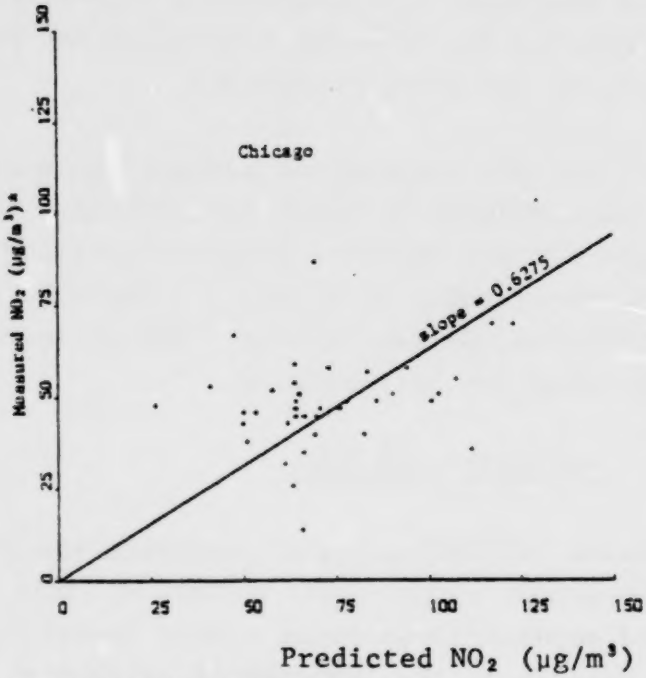
Figure 2. Chicago Wind Rose



Recorded 1974 Annual NO_2 Averages
($\mu g/m^3$)

1.	49	11.	64	21.	56	31.	54
2.	67	12.	60	22.	96	32.	68
3.	58	13.	60	23.	49	33.	76
4.	79	14.	56	24.	54	34.	41
5.	67	15.	52	25.	55	35.	54
6.	66	16.	56	26.	47	36.	55
7.	60	17.	58	27.	45	37.	44
8.	58	18.	58	28.	52	38.	47
9.	62	19.	56	29.	61	39.	35
10.	79	20.	60.	30.	63	40.	23

Figure 3. Location of Monitoring Points Used for Model Calibration - Chicago



* 10 µg/m^3 subtracted from each measurement to account for background.

Figure 4. Calibration Results

c. Annual Average Concentrations

Isopleths of predicted NO_2 concentration for each of the major source categories (large point sources, other point sources, vehicular area, other area) are presented in Figures 5 through 8. These isopleths are concentration contours or lines along which a pollutant's concentration is constant. Figure 9 is the composite isopleth map presenting the predicted impact from all sources including background.

Table 3 gives the maximum and average contribution from each source class modeled in Chicago. 'Average' values in Table 3 are averages for all receptor locations falling within the isopleth map boundary shown in Figure 1. The concentrations in Table 3 are calibrated CDM predictions. The estimated back ground level is included for completeness.

d. 'Hot-Spot' Analysis

The results of the 'hot-spot' analysis are presented in Table 4. The breakdown in the first column of Table 4 applies to the locations of maximum large point source impact in the AQCR. The second column applies to the location of maximum overall prediction which is the location of maximum impact from area sources. The levels presented in Table 4 are averages for two or three of the highest predictions for each type of location. The general location of the predicted maximum point source impact (first column) is UTM (437,4633) shown in Figure 1. The general location of overall maximum impact (second column) is UTM (433,4638). A point-by-point breakdown of this analysis is presented in Appendix E.

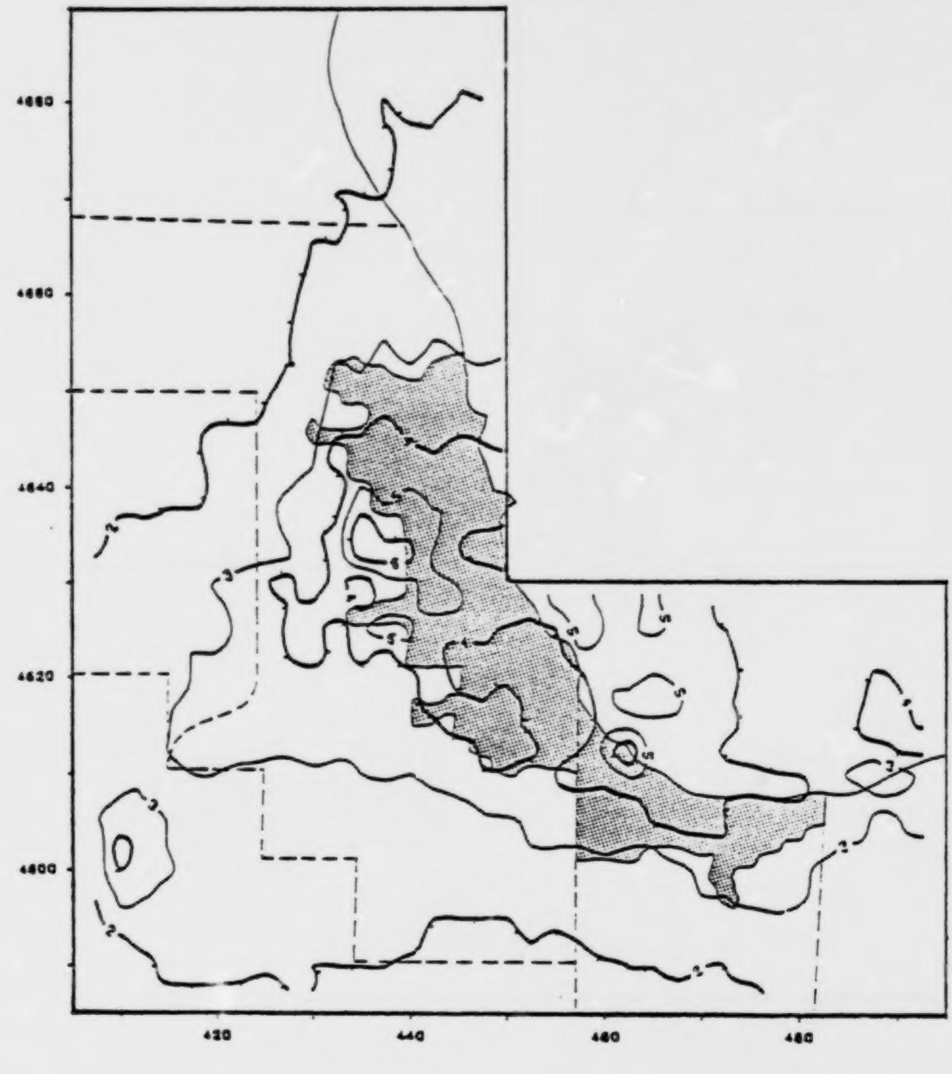


Figure 5. Predicted NO_2 Concentration ($\mu g/m^3$) Impact from Utility and Industrial Boilers - Chicago

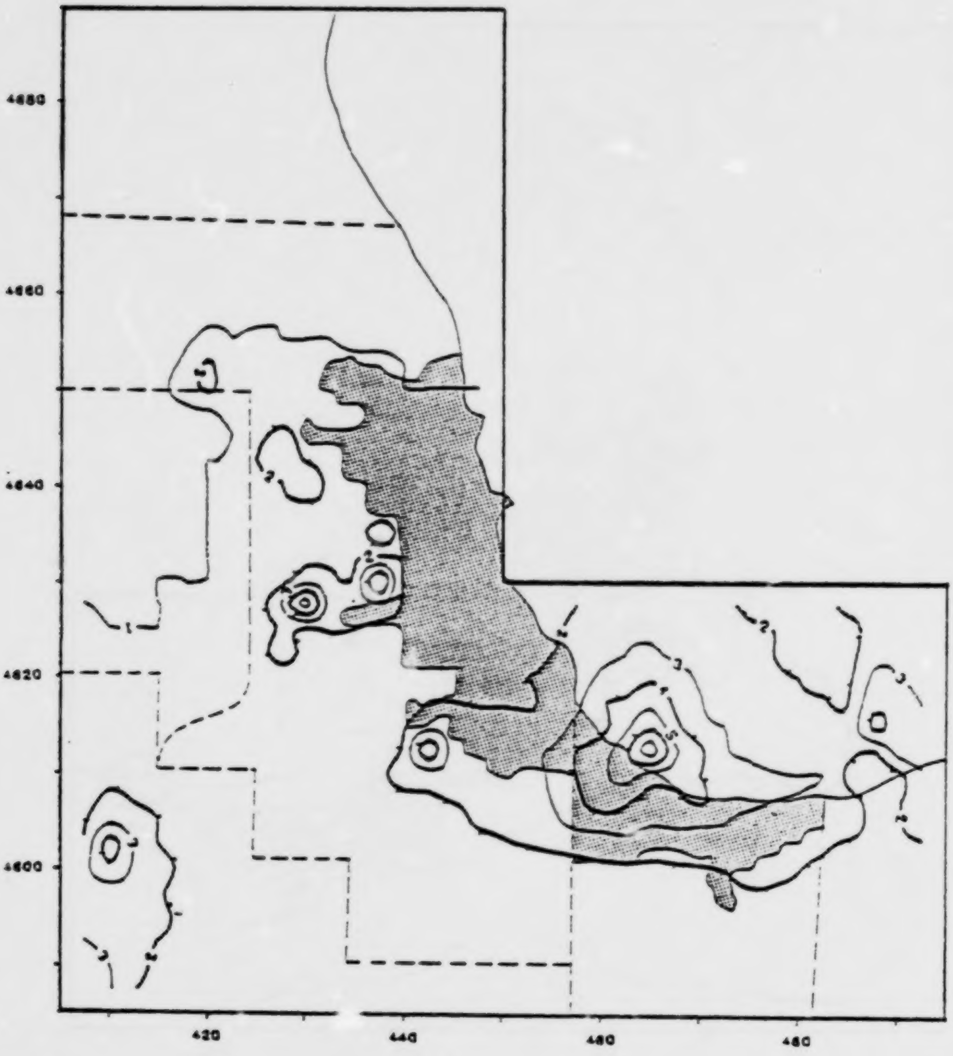


Figure 6. Predicted NO_2 Concentration ($\mu g/m^3$) Impact from Other Point Sources - Chicago

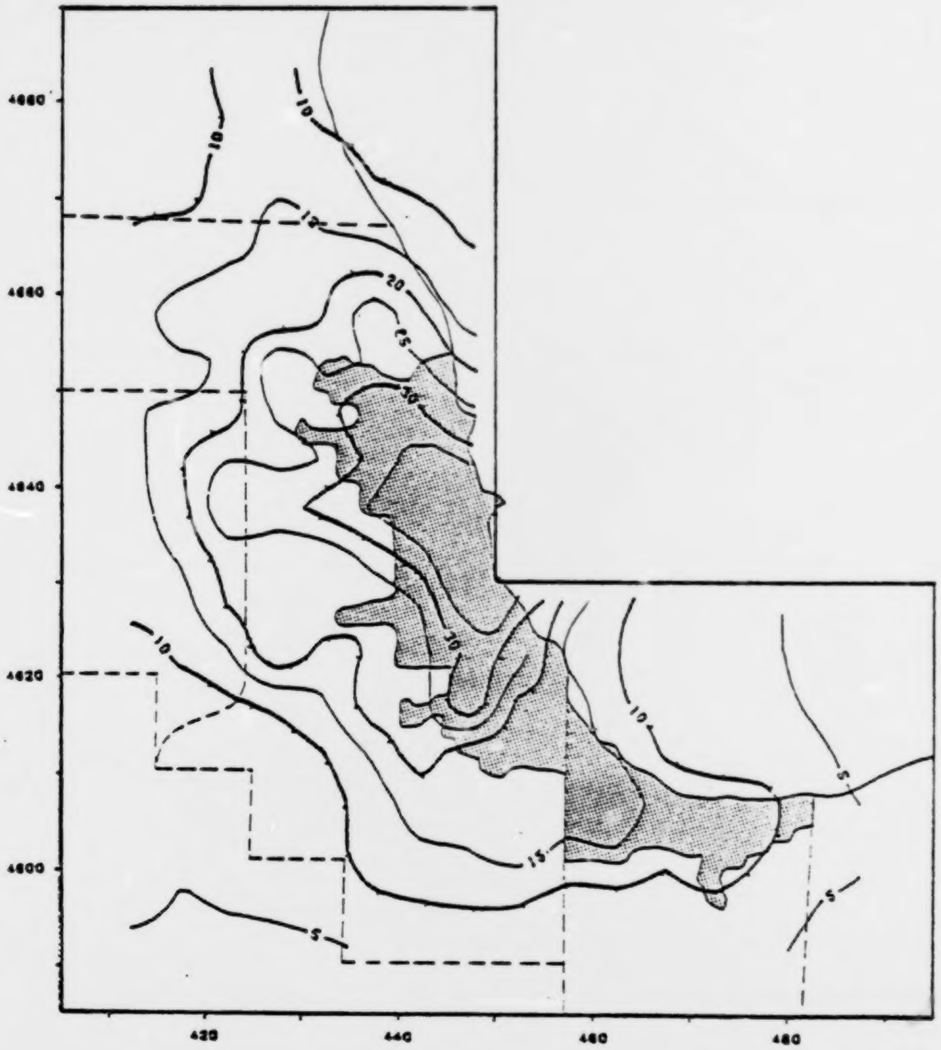


Figure 7. Predicted NO_2 Concentration ($\mu g/m^3$) Impact from Vehicular Area Sources - Chicago

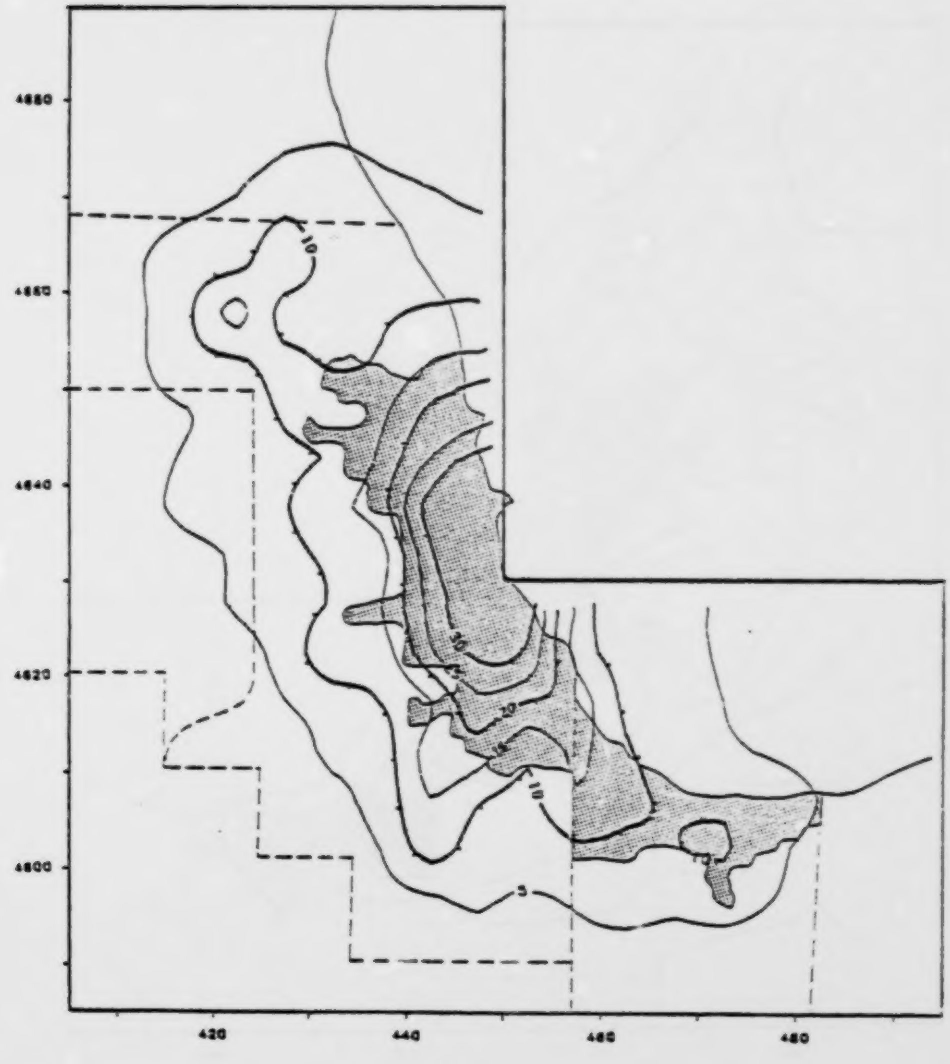


Figure 8. Predicted NO_2 Concentration ($\mu g/m^3$) Impact from Other Area Sources - Chicago

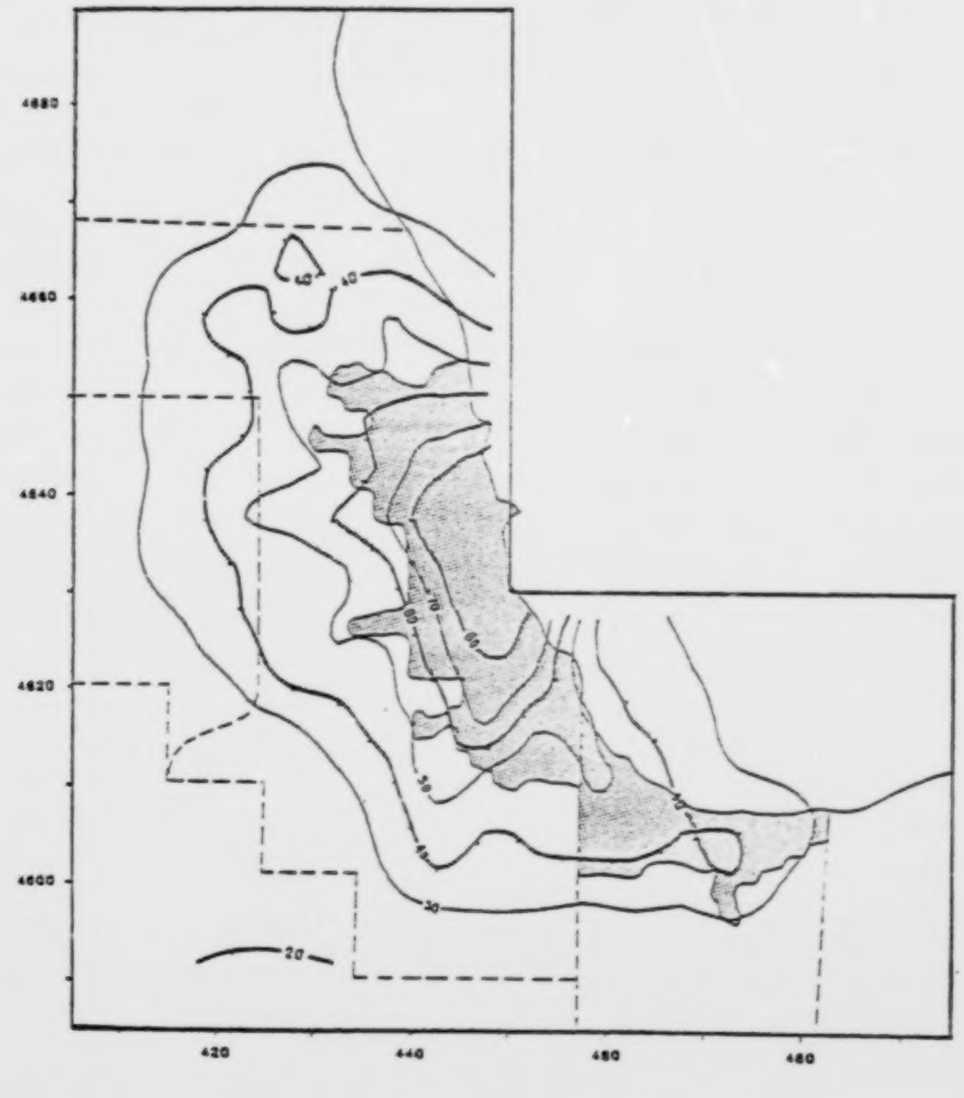


Figure 9. Predicted NO_2 Concentration ($\mu g/m^3$) Impact from All Sources Including Background - Chicago

TABLE 3. ANNUAL NO_2 AIR QUALITY PREDICTIONS BY SOURCE CLASS FOR CHICAGO ($\mu g/m^3$)

Class Description	Maximum	Average	(% of Total Average)
Electric Utilities Coal	4.7	1.8	(5.6%)
Electric Utilities Oil	1.1	0.3	(0.9%)
Electric Utilities Gas	1.1	0.3	(1.0%)
Industrial Coal (>100 MMBtu)	1.7	0.1	(0.4%)
Industrial Oil (>100 MMBtu)	1.1	0.1	(0.4%)
Industrial Gas (>100 MMBtu)	2.5	0.2	(0.5%)
Industrial Coal (<100 MMBtu)	3.0	0.3	(0.9%)
Industrial Oil (<100 MMBtu)	3.5	0.1	(0.4%)
Industrial Gas (<100 MMBtu)	2.0	0.4	(1.1%)
Commercial/Institutional Boiler	0.3	0.1	(0.1%)
Industrial Processes	5.5	0.8	(2.4%)
Solid Waste	0.6	0.1	(0.2%)
Vehicular Area Sources	44.0	11.6	(35.2%)
Other Area Sources	33.2	6.7	(20.4%)
Background	-	10.0	(30.4%)
Total		32.9	

TABLE 4. PREDICTED ANNUAL AVERAGE NO_2 CONCENTRATION AT SELECTED POINTS OF INTEREST IN CHICAGO ($\mu g/m^3$)

Source Class	Point Source Maximum Impact	Area Source Maximum Impact/City Center
Large Point Sources	7.5 (12%)	5 (6%)
Other Points	2.5 (4%)	2 (2%)
Vehicular	25 (42%)	42 (47%)
Other Area	15 (25%)	31 (34%)
Background	10 (17%)	10 (11%)
Total	60	90

B. Short-Term Impacts

1. Basic Approach

The purpose of Phase II was to estimate short-term (1-hour) NO_2 impacts in the Chicago AQCR and, again, to assess the improvement in air quality that could be realized by implementing NO_x controls on point sources. Scenarios representative of periods when high ambient NO_x concentrations might occur were selected for study. Annual average emissions data from Phase I were adjusted to account for diurnal and seasonal variations except in the case of Commonwealth Edison (CE) electric generating stations which were determined from actual CE test data. Vehicular emissions data were adjusted for 1985 to reflect the most recently promulgated motor vehicles emission limitations. Actual fuel send-out data for Chicago was used to estimate short-term area source emissions from the annual area source emissions data.

The short-term model used was developed by Radian and employed accepted Gaussian modeling techniques. Due to the lack of sufficient continuous monitoring data (only two stations were operational), the short-term model could not be calibrated. However, the data from the two continuous monitoring stations were used to define NO_2/NO_x ratios for the scenarios selected for study. The procedure used to define these ratios is discussed below in Section IV.B.3.c. The impact of point source controls on ambient NO_2 levels is addressed for both 1975 baseline and 1985 growth projection cases.

2. Data Collection and Presentation

a. Air Quality Monitoring Data

Figures 10 and 11 show the diurnal variation of NO_x and NO_2 levels for winter and summer seasons for 1975 at the Plymouth Court (Camp) and West Polk (Med. Center) monitoring station, respectively. This information was used to help identify the scenarios of concern and also to establish NO_2/NO_x ratios for each scenario.

b. Power Plant Emissions

Hourly power plant emissions were evaluated in detail for 1975 and 1985. Both utility-owned and non-utility power plants were included. For the "typical" case, unit emissions were based upon electrical demand curves as functions of time of day and season of year. For "worst case" conditions, all units were assigned summer and winter emissions corresponding to loads of 90 percent and 95 percent, respectively. These emissions are applicable to both 1975 and 1985.

Commonwealth Edison (CE), the largest electrical utility in the Chicago AQCR, has performed NO_x emissions tests on some of its steam units. Technical data on these tests are given in Appendix F. Where available, CE test data were used to estimate short-term emissions. Emissions for those CE units not tested were based upon EPA's AP-42 emission factors and boiler operational data. Table 5 gives unit NO_x emissions for all CE fossil-fueled steam units in the Chicago AQCR. Emissions shown in Table 5 are based upon one of three different calculation methods given below.

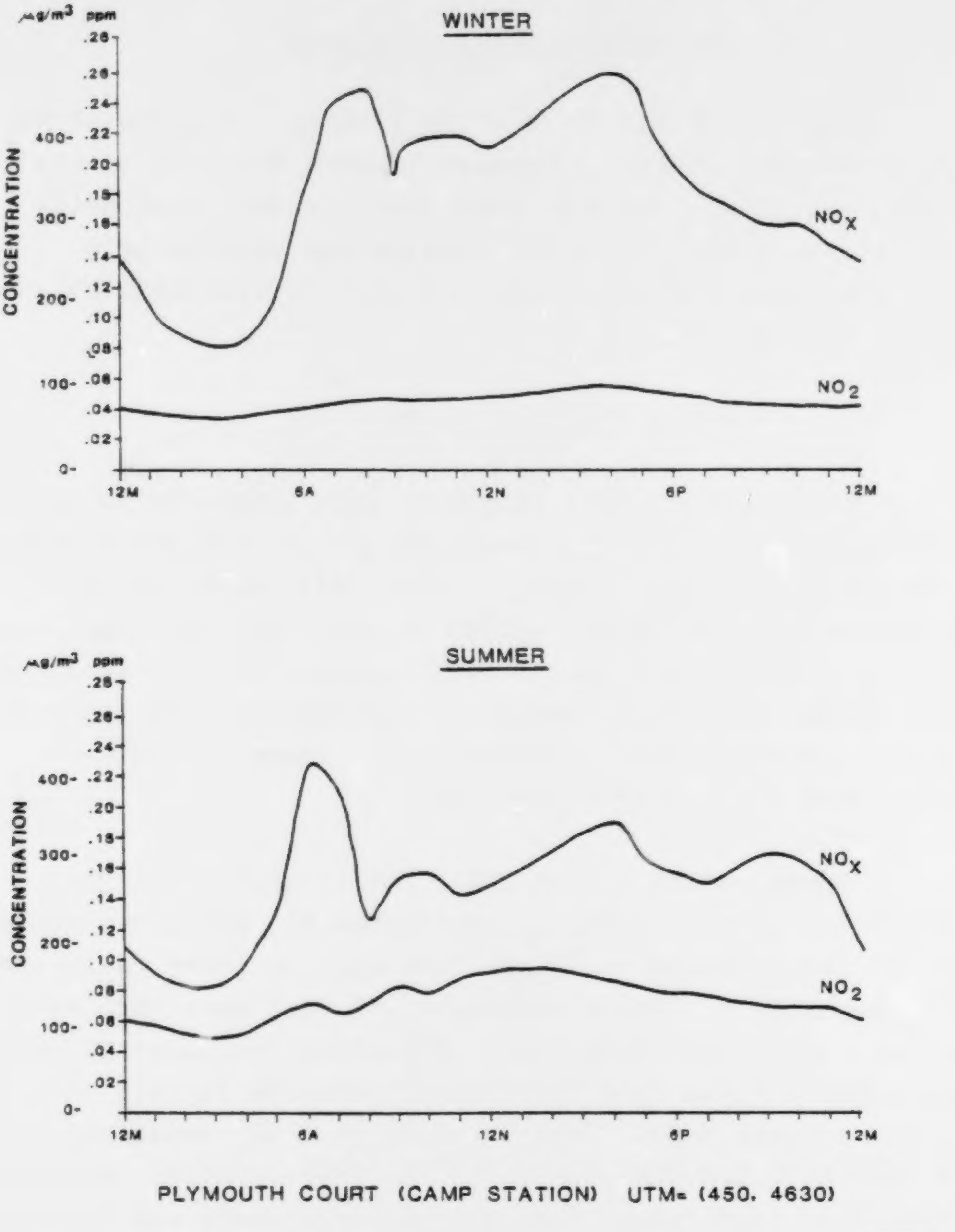


Figure 10. Seasonal-Diurnal Variation in NO_x and NO_2 for Plymouth Court Monitoring Station

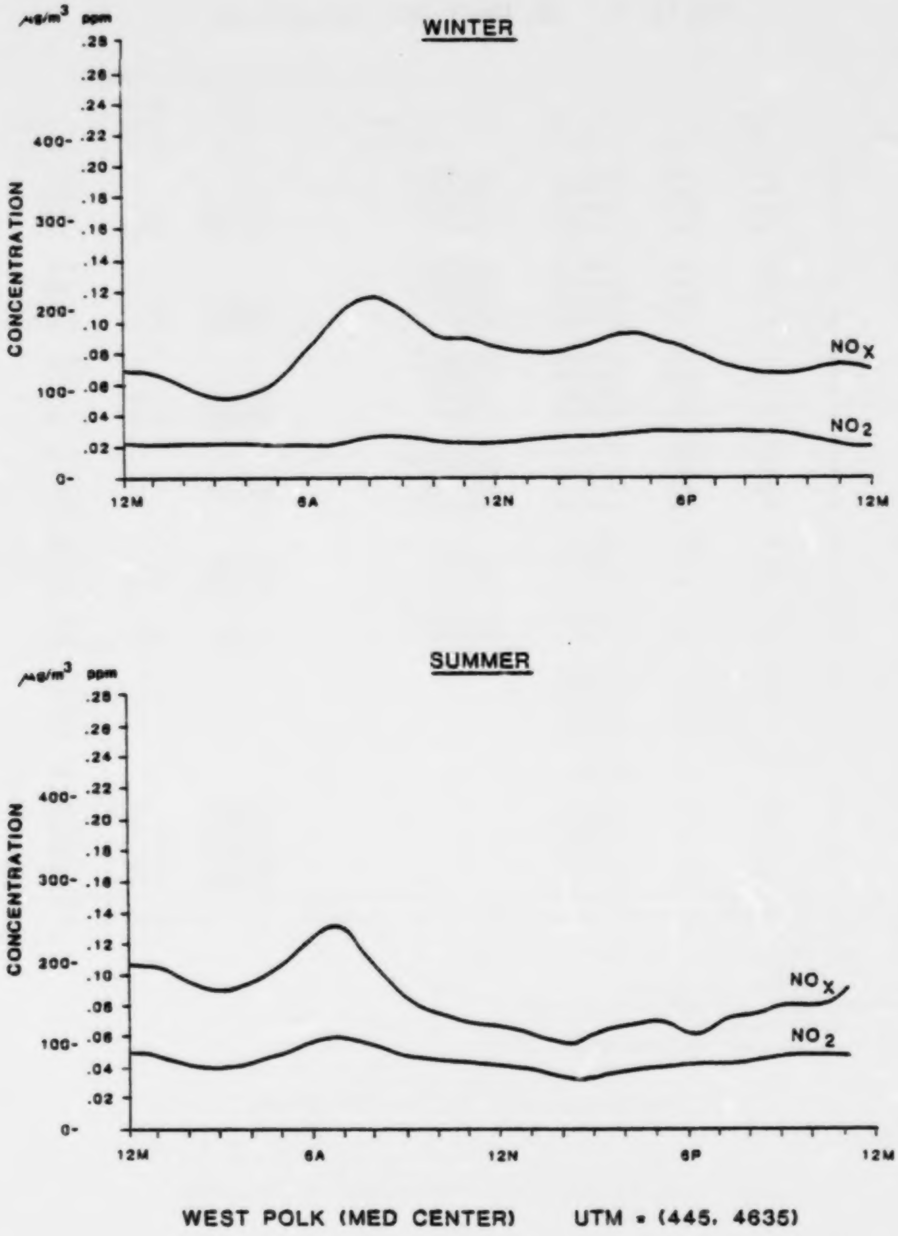


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Figure 11. Seasonal-Diurnal Variation in NO_x and NO_2 for West Polk Monitoring Station

Table 5. CE Unit NO$_x$ Emissions

Plant/Unit		Exist 1985	Fuel	Form 67 & AP42(#1)	Total NO$_x$ Lb/Hr (Given as NO$_x$@Mw) Util.H.R.,NOM.H.H.V. & AP42(#2)	Util. Test (#3)	Ratio (#2)/(#3)	Value Used
Joliet	5	Yes	LSWC	4070@107	2327@85^{u+}	-	-	2327
	6	Yes	LSWC	7920@360	8268@340^{u+}			8268
	7	Yes	LSWC	5220@660	4451@581	7248@581	0.61	7248
	8	Yes	LSWC	5220@660	4405@575	6763@575	0.61	6763
Waukegan	5	Yes	LSWC	2280@115	2067@122^{u+}	-	-	2067
	6	Yes	LSWC	3080@121	2199@88^{u+}	-	-	2199
	7	Yes	LSWC	2484@326	2242@305	3346@305	0.67	3598@328^{u++}
	8	Yes	LSWC	2700@355	2390@305	2906@305	0.82	3391@358^{u++}
Will County	1	Yes	LSWC	4444@188	4024@144^{u+}	-	-	4024
	2	Yes	LSWC	4444@184	4716@167^{u+}	-	-	4716
	3	Yes	LSWC	2250@299	1922@217	1888@217	1.02	2277@262^{u++}
	4	Yes	LSWC	4032@598	4139@455	4109@455	1.01	4109
State Line	1	Yes	LSWC	3168@208	2260@171^{u+}	-	-	2260
	2	Yes	LSWC	2250@150	2157@140^{u+}	-	-	2157
	3	Yes	LSWC	2520@225	2877@238	1953@238	1.47	1953
	4	Yes	LSWC	6820@389	7369@31[illegible]$^{u+}$	-	-	7369
Crawford	6	No	Gas	895@104	-	-	-	895
	7	Yes	LSWC	1800@239	1810@205	1082@205	1.67	1171@222^{u+}
	8	Yes	LSWC	2610@358	3048@360	2592@360	1.18	2592
Fisk	18	Yes	LSWC	4895@173	4135@129^{u+}	-	-	4135
	19	Yes	LSWC	2502@374	2923@343	3163@343	0.92	3163
Ridgeland	1	Yes	Oil	1317@173	-	-	-	1317
	2	Yes	Oil	1317@173	-	-	-	1317
	3	Yes	Oil	1141@173	-	-	-	1141
	4	Yes	Oil	1141@173	-	-	-	1141
Calumet	7	No	Gas	435@107	-	-	-	435
Collins	1	Yes*	Oil	3859@520	-	1266@520	3.05**	1266
	2	Yes*	Oil	3859@520	-	1266@520	3.05**	1266
	3	Yes*	Oil	3859@503	-	1224@503	3.15**	1224
	4	Yes*	Oil	3859@503	-	1224@503	3.15**	1224
	5	Yes*	Oil	3859@503	-	1224@503	3.15**	1224

++Unit curtailed during test due to mechanical failure or other problem - linear extrapolation used based on utility data.

+Uses avg. coal H.H.V. from test on other units in plant

*Did not exist in 1975

**(Form 67 & AP42)/(#3)

^{u}Net capability provided by utility

LSWC - Low sulfur western coal

Underlined values are basis for values used.

(1) In plants where no testing was done, Federal Power Commission (FPC) Form 67 boiler data were used with AP-42 emission factors.

(2) For untested units in plants where testing was done, an average higher heating value (HHV) based on coal HHV from tests was used with AP-42 emission factors and unit heat rate data furnished by CE.

(3) For tested units, test results were used.

Other utility-owned steam power plants in the Chicago AQCR are Northern Indiana Public Service Company's (NIPSCO) Mitchell and Bailly Stations and the Village of Winnetka's city-owned station. Emissions for their units are given in Table 6. Non-utility steam power plants in Chicago include Bethlehem Steel (5 units) and Texaco (1 unit). Emissions for these plants are given in Table 7. Emissions test and calculation data for combustion turbine (CT) and other peaking units are given in Appendix G.

Plant locations are given in Figure 12. A more detailed discussion of power plant emissions characterization including demand curves and projected typical loadings for 1985 is given in Appendix H.

c. Other Point Source Emissions

A number of other point sources were included in this study. Data concerning these sources were obtained from the NEDS and Illinois EPA (ILLEPA) inventories. All sources were catalogued, coded, and expected hourly emissions were determined. Several sources, including several NIKE bases, post offices, etc., were omitted either as being inconsequential or

TABLE 6. NIPSCO AND WINNETKA POWER PLANT NO_x EMISSIONS DATA

Plant/Unit		Max MWe	Type	Max Hourly NO_x (lb/hr)
Mitchell	4	138	Dry Bottom	1004
	5	138	Dry Bottom	1004
	6	138	Dry Bottom	1004
	11	115	Dry Bottom	882
Bailly	7	194	Cyclone	4950
	8	422	Cyclone	10,010
Winnetka*				
	1	25.5	Stoker/gas	362
	2	25.5	Stoker/gas	362

*Winnetka boilers 2, 3, & 4 are normally shut down; boiler 1 or 5 is usually run with the other on hot reserve status.

TABLE 7. NON-UTILITY POWER PLANT NO_x EMISSIONS DATA

Plant/Unit		Probable Type	Expected Maximum Hourly NO_x (lb/hr)
Bethlehem Steel	1	multi-fuel*	2027
	2	multi-fuel*	2027
	3	multi-fuel*	2027
	4	multi-fuel*	2027
	5	multi-fuel*	2027
Texaco	1	gas/oil	86

*Distillate oil, natural gas, propane, coke gas, and blast furnace gas.

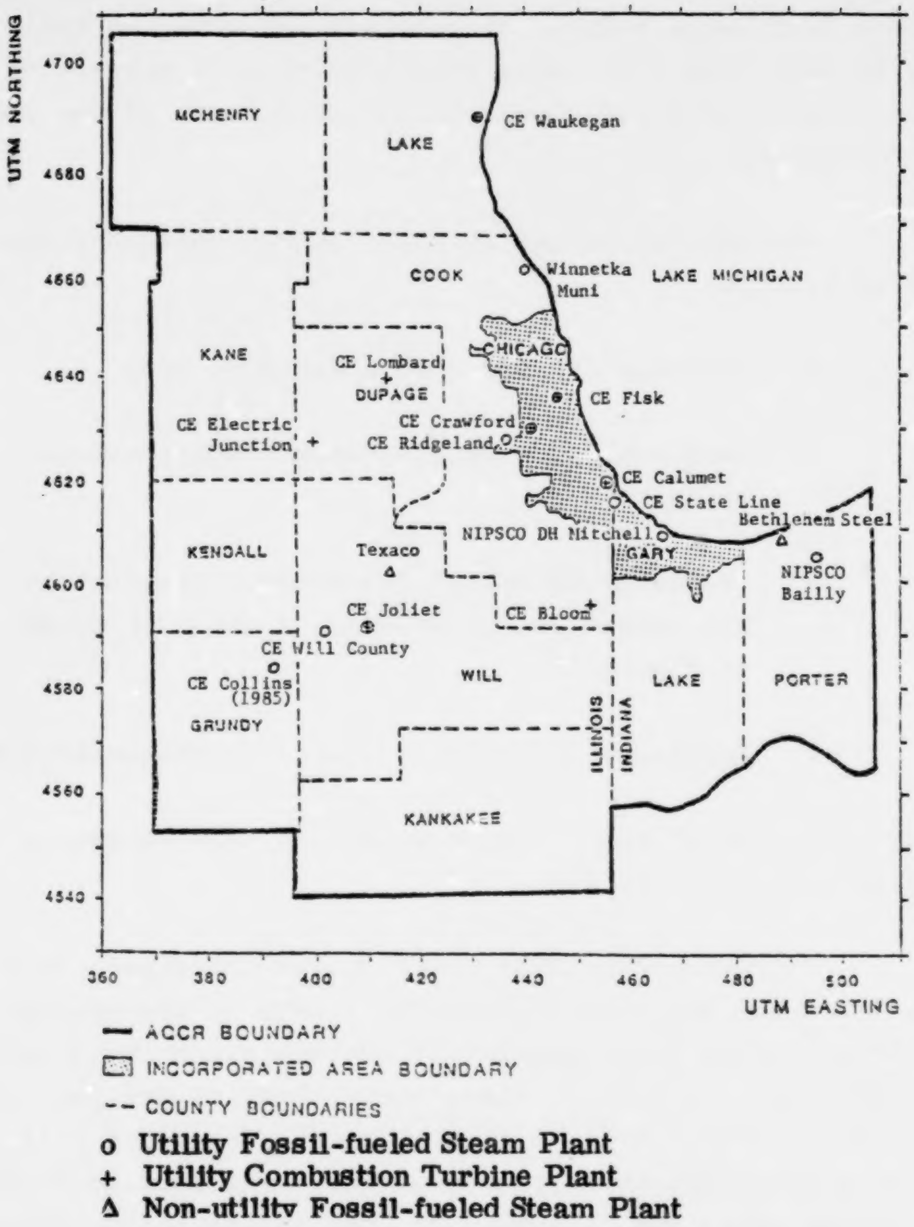


Figure 12. Power Plants in Chicago AQCR

because data were unavailable. Point sources used in this study are categorized in Table 8 and the number of sources actually in operation for various scenarios is given in Table 9. These sources were further classified as large and small; expected emissions from large sources by category are shown in Table 10. It may be seen from this table that less than 15 percent of the sources studied produced approximately 80 percent of the point source emissions.

Diurnal variations in point source emissions were estimated based on:

1. Illinois EPA and NEDS operations data.

2. Knowledge of electric demand contributions by segment.

3. Knowledge of hourly gas sendout provided by gas companies, an example of which is shown in Figure 13.

4. Knowledge of industry process characteristics.

In many cases, large point source emissions were estimated to be constant throughout the day.

With regard to 1985 point source emissions, very little data were available concerning growth in the Chicago AQCR; the only published data immediately available concerned Lake and Porter Counties, Indiana.[2] Since these counties are part of the Chicago metropolitan area, a general growth factor of 1.35, based on average growth in these counties, was used to scale point source emissions. Because of the changeover in fuels, and the increased emphasis on industrial energy conservation, it is believed that this factor is reasonable.

TABLE 8. NUMBER OF POINT SOURCES BY CATEGORY

Source	Metal Refining, Smelting, etc.	Petro-Chemical	Fabrication	Food Processing	Institutional	Heating Only	Other or Unidentified
ILLEPA Ambient*	0	0	0	0	1	0	5
NEDS Ambient*	0	0	0	0	0	2	1
ILLEPA Stack	4	33	16	8	7	30	18
NEDS Stack	55	130	59	24	26	41	79
Total Sources	59	163	75	32	34	73	103

*Exit temperature same as ambient.

TABLE 9. NUMBER OF POINT SOURCES IN OPERATION FOR STUDY

Source	Max. Possible	Summer			Winter		
		Mid PM	Mid AM	Early AM	Mid PM	Mid AM	Early AM
ILLEPA Ambient	6	6	6	6	6	6	6
NEDS Ambient	3	1	1	0	3	3	1
ILLEPA Stack	116	86	86	75	114	115	99
NEDS Stack	414	372	372	295	414	410	324
Total Sources	539	465	465	376	537	534	430

TABLE 10. LARGE POINT SOURCES STUDIED

Emissions by Source Type	Summer			Winter		
	Mid PM	Mid AM	Early AM	Mid PM	Mid AM	Early AM
Metal Refining, Smelting, etc.						
100-1000 lb/hr	10/2439*	10/2419	9/2239	11/2573	11/2553	10/2373
Petrochemical						
100-1000 lb/hr	20/4050	20/4050	20/4050	20/4050	20/4050	20/4050
1000-5000 lb/hr	0	1/5000	0	0	0	0
>5000 lb/hr	1/7875	0	0	0	0	0
Fabrication						
100-1000 lb/hr	4/547	1/200	0	4/547	1/200	0
1000-5000 lb/hr	10/24,080	10/24,080	10/24,080	10/24,080	10/24,080	10/24,080
Food Processing						
100-1000 lb/hr	1/120	1/120	1/120	1/120	1/120	1/120
Institutional						
100-1000 lb/hr	1/192	1/192	1/192	1/192	1/192	1/192
Heating Only						
100-1000 lb/hr	0	0	0	4/883	4/883	2/281
Other or Unidentified						
100-1000 lb/hr	14/3845	14/3833	5/1574	14/3854	14/3842	5/1583
Total Emissions for Above Sources	61/43,148	58/39,894	46/32,255	65/36,299	62/35,920	49/32,679
Total Emissions for all Sources	465/51,042	465/47,853	376/38,660	537/45,519	534/45,088	430/40,173
Percentage of Total for Above Sources (per hour)	13.1%/84.5%	12.5%/83.4%	12.2%/83.4%	12.1%/79.7%	11.6%/79.7%	11.4%/81.3%

*(No. of Sources)/(total lb/hr NO_x emitted)

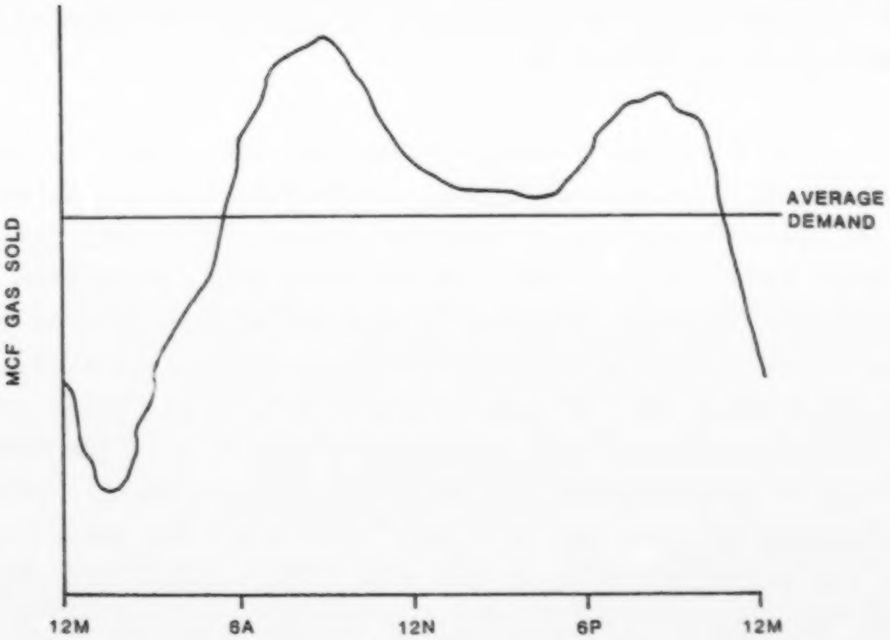


Figure 13. Typical NIPSCO Hourly Gas Demand for July 1975, Week Day

d. Vehicular Sources

This section describes the data and methods used to estimate seasonal and diurnal NO_x emissions for vehicular emissions. The basic data source was the Chicago Area Transportation Study (CATS). Data supplied by CATS were used to convert 1975 annual average emissions to hourly averages for morning and afternoon periods in the summer and afternoon periods in the winter. In addition, a description of projection factors for 1985 emissions is presented.

The first step was to determine the effect of temperature on annual average emissions. CATS supplied estimates of zonal NO_x emissions for the "average" case (65°F) and the typical winter case (24°F). The average case emissions (tons per day) had been used to construct annual emissions for the annual average modeling portion of this study (see Section IV.A). The winter case emissions divided by the average case emissions equal the temperature factor, approximately 1.17. The temperature dependence was determined by CATS using the parametric equations in Supplement No. 5 to AP-42. CATS is now in the process of updating its emissions data to the more recent Supplement No. 8. For the purposes of this study, the factor 1.17 was applied for all areas of the AQCR.

The time-of-day emission level was estimated by using diurnal traffic patterns for arterial streets and freeways as supplied by CATS. These data consisted of hour-by-hour percentages of daily vehicle miles traveled (VMT) for various areas in the study area. That is, these hourly factors, termed "trip fractions" multiplied times daily emissions yield an estimate of hourly emissions, with all other parameters assumed constant. Appplication of these data to the NO_x study involved the following steps.

First, the hourly trip fractions for the hours 6-9 AM and 3-6 PM were averaged arithmetically to obtain average morning and average afternoon hourly trip fractions. This was done to avoid overestimation of emissions due to peak hourly trip fractions.

Next a methodology was developed to transfer the CATS hourly trip fractions to the annual average emissions as gridded in 5 x 5 Km squares. The CATS data were supplied in geographical "districts" and "rings". Trip fractions in districts were applicable to VMT on arterial streets; trip fractions in rings were applicable to freeway travel.

To preserve the spatial resolution of the CATS data, the annual average NO_x emissions in each 5 x 5 Km square were adjusted by a factor which accounted for hourly trip fractions on both arterial streets and freeways. This factor, the emission scale factor (ESF), was determined as follows.

The NO_x emissions in each CATS zone and, therefore, in each 5 x 5 Km grid, account for travel on arterial streets and freeways. CATS could not readily provide the breakdown of arterial versus freeway emission in each zone, but the VMT magnitudes were available. CATS also estimates unique average arterial and freeway speeds for each zone.

For this study the following speeds were chosen: 20 mph, arterial streets and 45 mph, freeways. Assuming all other parameters constant, average speed is the main difference between the NO_x emission factor for arterial and freeway travel. For the nationwide vehicle mix reported in AP-42, the ratio of NO_x emissions at 45 mph to NO_x emissions at 20 mph is approximately 1.6.

Using the average hourly trip fractions, VMT, and emission factor ratio described above, the morning and afternoon ESF's were computed for each 5 x 5 Km grid. For Cook County each grid was analyzed individually, while for the remaining counties an average ESF was applied to all grids within the county. The equation used to compute the ESF is shown below:

$$\text{ESF (AM or PM)} = \frac{\text{(FWY VMT) (FWY HTF) (1.6) + (ART VMT) (HTF)}}{\text{(FWY VMT) (1.6) + (ART VMT)}}$$

where

ESF = emission scale factor: the NO_x hourly emissions (tons per hour) = ESF X annual average emissions (tons per day)

FWY VMT = annual average daily vehicle miles traveled on freeways

FWY ART = annual average daily vehicle miles traveled on arterial streets

SWY HTF = hourly trip fraction for freeways, i.e., the hourly freeway VMT divided by the daily VMT

ART HTF = as above, for arterial streets.

As mentioned, the above equation was applied at the grid level for Cook County. That is, a grid-specific AM and PM emission scale factor was computed for all 5 x 5 Km grids in Cook County. In the other counties, the ESF was computed for the county and applied to all grids within the county. A summary of these results is shown in Table 11.

TABLE 11. VEHICULAR SCALE FACTORS AND 1975 VMT BY COUNTY

	1975 Annual Average Daily VMT (1,000's)		FWY HTF		ART HTF		ESF	
County	FWY	ART	AM	PM	AM	PM	AM	PM
Cook	21,515	52,799					GL	GL
DuPage	2,210	9,424	.053	.070	.042	.071	.046	.070
Grundy	ND	ND					.040*	.071*
Kane	350.2	3,134	.045	.072	.039	.070	.040	.071
KanKaKee	ND	ND					.040*	.071*
Kendall	ND	ND					.040*	.071*
Lake	1,386	6,274	.053	.074	.040	.077	.043	.076
McHenry	23.9	1,504	.045	.072	.035	.067	.036	.068
Will	1,242	3,446	.053	.074	.036	.066	.042	.069
Lake, IN	2,410	5,668	.053	.070	.036	.069	.043	.070
Porter, IN	300	1,089	.053	.074	.036	.069	.041	.070

ND = no data

GL = Averaging was performed at grid level.

*Assumed the same as Kane County.

1985 Projections

To estimate the impact of the most recent Clean Air Act Amendments, 1985 projection factors for vehicular emissions were computed for the three short-term study periods. The 1985 projections take into account (1) the ratio of 1985 to 1975 vehicle mix average emission factors, and (2) the ratio of 1985 and 1975 total vehicle miles for the study area. Emission factors for 1985 were computed using the emission levels specified in the 1977 Clean Air Act Amendments. These levels are 2.0 g/mi for new light duty vehicles manufactured through 1980 and 1.0 g/mi for those produced in subsequent years. These projected new vehicle emission factors were applied to the 1975 percent annual travel by vehicle age supplied by CATS to obtain the composite emission factor. The revised computation methods in AP-42, Supplement No. 8, were used. The results are shown below:

Summer Period	1985/1975 Ratio of Emission Factors	x	1985/1975 Ratio of VMT	=	Net Projection Factor
Summer Afternoon	0.477		1.075		0.513
Summer Morning	0.473		1.075		0.509
Winter Morning	0.472		1.075		0.508

e. Non-Vehicular Sources

Non-vehicular source emission data were obtained from the annual average case which was previously discussed. Each source was considered to be a 5-by-5 kilometer square with the emissions distributed uniformly over the area.

Diurnal and seasonal variations were scaled from gas sendout data furnished by NIPSCO and Northern Illinois Gas Co. (NIGC). These data are shown in Appendix I; a typical NIPSCO daily gas load curve was previously shown in Figure 13. From these data, the scale factors in Table 12 were determined. These factors are multiplied by the annual average emission rate to produce a diurnally/seasonally scaled hourly rate. These scale factors were based on gas sendout and the NIPSCO load curve and reflect the inclusion of the following groups of purchasers:

- Residential
- Commercial
- 20 percent of Industrial (the other 80 percent is included in the point source inventory)
- Other

It is believed that these factors are reasonable and that they somewhat make up for any inaccuracies in the point source (primarily industrial) data. For 1985, the growth factor of 1.35 was used as was the case for point sources.

3. Modeling Approach

a. Model Description

The short-term dispersion model used in this study is capable of predicting average concentrations for time periods ranging from several minutes to several hours. The option exists of subdividing a given averaging period into smaller time intervals with specified plant emissions and meteorological conditions which are assumed constant within that time interval, but which can change from interval to interval. The model solves the Gaussian dispersion equation for each of

TABLE 12. DIURNAL/SEASONAL SCALE FACTORS FOR NON-VEHICULAR SOURCES

LOCATION	SUMMER A.M.	SUMMER P.M.	WINTER A.M.
Lake County, Indiana	0.83	0.83	3.01
Porter County, Indiana	0.78	0.65	2.48
All Illinois	0.60	0.50	3.07
Percent of Hourly Average	150%	125%	170%

*Based on NIPSCO Load Curve

these intervals, and computes the final average concentration as a weighted average of the contributions from the individual time increments.

The one-hour NO_x predictions of this study were computed using the RAM[3] formulation of the Gaussian equation, and the Pasquill-Gifford dispersion coefficients as described by Turner.[4] The plume rise for neutral and unstable conditions was computed with the 1970 "X_2" formula developed by Briggs in 1970.[5] Area source analyses employed a two-dimensional numerical integration scheme, and the same grid system that was used for the annual modeling.

The model input consists of two classes of data. The first describes the atmospheric conditions during which the pollutant is being dispersed, while the second class deals with emission rates and stack parameters. The NO_x emission rates for all of the sources have been scaled as described previously.

b. Meteorological Conditions

The most important meteorological conditions for dispersion analysis are the wind speed, mixing depth, and stability class. The wind speed is required to compute the plume rise. For a given stability class, the plume rise is inversely proportional to the wind speed. The mixing depth determines the volume of air through which a plume is able to disperse.

Stability classes characterize the ability of the lower part of the atmosphere to disperse emission products. Dispersion modeling employs six such classes, each of which has a unique dispersion capability. These classes have been designated as A, B, C, D, E, and F, respectively, and as such, represent a sequence of increasingly stable conditions. In general, as the air becomes more stable, its capabilities to mix and disperse pollutants decreases. During the night neutral or stable conditions occur whereas during the day neutral or unstable conditions occur. The most unstable conditions occur in mid-summer on clear days with light winds in the early afternoon, and the most stable conditions occur on clear nights with light winds.

Large groundlevel NO_x concentrations can be produced by tall point sources during a set of meteorological circumstances known as limited mixing. A ground based nighttime stable layer traps an elevated plume and prevents it from either dispersing significantly or reaching the ground. During the subsequent decay of the stable layer by strong solar heating of the ground, a rapid downward mixing of the trapped plume occurs resulting in high groundlevel concentrations which may persist for an hour or more.

Maximum groundlevel concentrations of pollutants emitted from tall stacks are also encountered during periods of atmospheric instability. The strong ground based turbulence which is characteristic of unstable conditions facilitates a rapid downward transport of the effluent before significant mixing can occur. In contrast, the largest impacts from groundlevel sources, such as vehicles, and area sources occur when the atmosphere is quite stable. At such times the emissions from low-level sources cannot effectively disperse, and are thus constrained to remain in a layer quite close to the ground. Consequently, the meteorological conditions that lead to maximum impacts for tall stacks and ground-level emissions are not the same. The two sets of atmospheric conditions, in fact, represent the opposite extremes of the stability class sequence. Therefore, it is not possible to maximize impacts from power plants and area sources simultaneously. It is important that this restriction be noted, because the current study focuses primarily on large-point sources and the meteorological conditions which will maximize the impact of these point sources.

Preliminary modeling indicated that the largest NO_x concentrations can be expected during conditions of limited mixing and stability classes B and C.

c. Selection of Scenarios

For the purposes of this study, NO_x emission sources have been classified as follows:

1. Power plants and affiliated combustion turbines
2. Large point sources
3. Vehicular area sources
4. All area sources.

The object of this investigation was the assessment of the impact of hourly emissions. Therefore, a realistic representation of these sources which takes into account the diurnal variation of their emissions was required. Since it was impossible to model every hourly case, a number of scenarios were developed to represent the most likely situations under which high NO_x and NO_2 concentrations are possible. Each scenario represents a combination of time dependent emission rates, meteorological conditions, and NO_x to NO_2 conversion rate.

Seven scenarios were intially identified as being representative of periods when high ambient NO_x and NO_2 concentrations can occur. They were chosen to represent the greatest diversity in NO_x emission rates and meteorological conditions. They are:

Summer Mid-Morning Typical
Summer and Winter Mid-Afternoon Typical
Summer and Winter Mid-Morning Worst
Summer and Winter Mid-Afternoon Worst

The "typical" scenarios are designed to maximize interactions between all point sources, while the "worst" scenarios are designed to maximize concentrations from large point sources. Power plants and point sources were modeled for the typical scenarios using the atmospheric conditions shown below:

Summer Mid-Morning Typical

Stability class:	C	Temperature:	70°F
Wind direction:	East	Wind speed:	9 K
Mixing depth	650 m		

Summer Mid-Afternoon Typical

Stability class:	D	Temperature:	80°F
Wind direction:	Southwest	Wind speed:	13.8 K
Mixing depth:	1600 m		

Winter Mid-Afternoon Typical

Stability class:	D	Temperature:	30°F
Wind direction:	West	Wind speed:	13.8 K
Mixing depth:	650 m		

Based on the results from this and some additional preliminary modeling for the worst case situations, the following three scenarios were selected as possessing the greatest potential for high NO_2 concentrations.

Summer mid-morning - worst: This scenario is most likely to occur on a power system peak day when all steam units are running at 90 percent of capacity due to cooling system limitations. In addition, point sources are beginning to peak. Vehicular emissions are moderately high, and area emissions are moderate. Temperature is warm with limited mixing dispersion conditions and a high NO_2/NO_x ratio of approximately one-half.

Summer mid-afternoon - worst: This scenario represents a summer power system peak which coincides with an unstable or neutral meteorological condition and a traffic peak. All steam generating units are at 90 percent capacity, point sources are high, as are vehicular sources and area sources. Temperature is hot with unstable conditions and a high NO_2/NO_x ratio of approximately one-half.

Winter mid-morning - worst: This scenario represents a power system peak in the Chicago area most likely caused by winter coal handling problems at the Kincaid and/or Powerton Plants. In general, the most likely causes of such a situation are frozen coal piles and coal transportation problems not uncommon to that area of the country. Steam units are at 95 percent of capacity due to cooling system limitations. In addition, point source emissions are high, area emissions are higher than summer, and vehicular sources are moderate. Temperature is low with limited mixing dispersion conditons and a low NO_2/NO_x ratio of approximately one-fourth.

NO_2/NO_x ratios for these cases were determined from data gathered at two continuous monitoring sites in the downtown Chicago area. Figures 10 and 11 in Section III.B.2., show the average diurnal variation of NO_2 and NO_x for summer and winter based on measured data for 1975. The NO_2/NO_x ratio for each scenario was determined by dividing the average NO_2 measurement for the appropriate time of day and season of year (e.g., mid-morning, summer) by the corresponding average NO_x measurement. This was done twice for each scenario - once using the Plymouth Court station data and again using the West Polk station data. The two were compared for consistency and averaged. The resulting NO_2/NO_x ratio was assumed to apply to the plume environment to allow groundlevel NO_2 concentrations to be calculated from predicted NO_x concentrations.

The summer mid-afternoon and winter mid-afternoon - typical scenarios were also included in the analysis to a limited extent to show the effect of multiple point source interactions on NO_x levels.

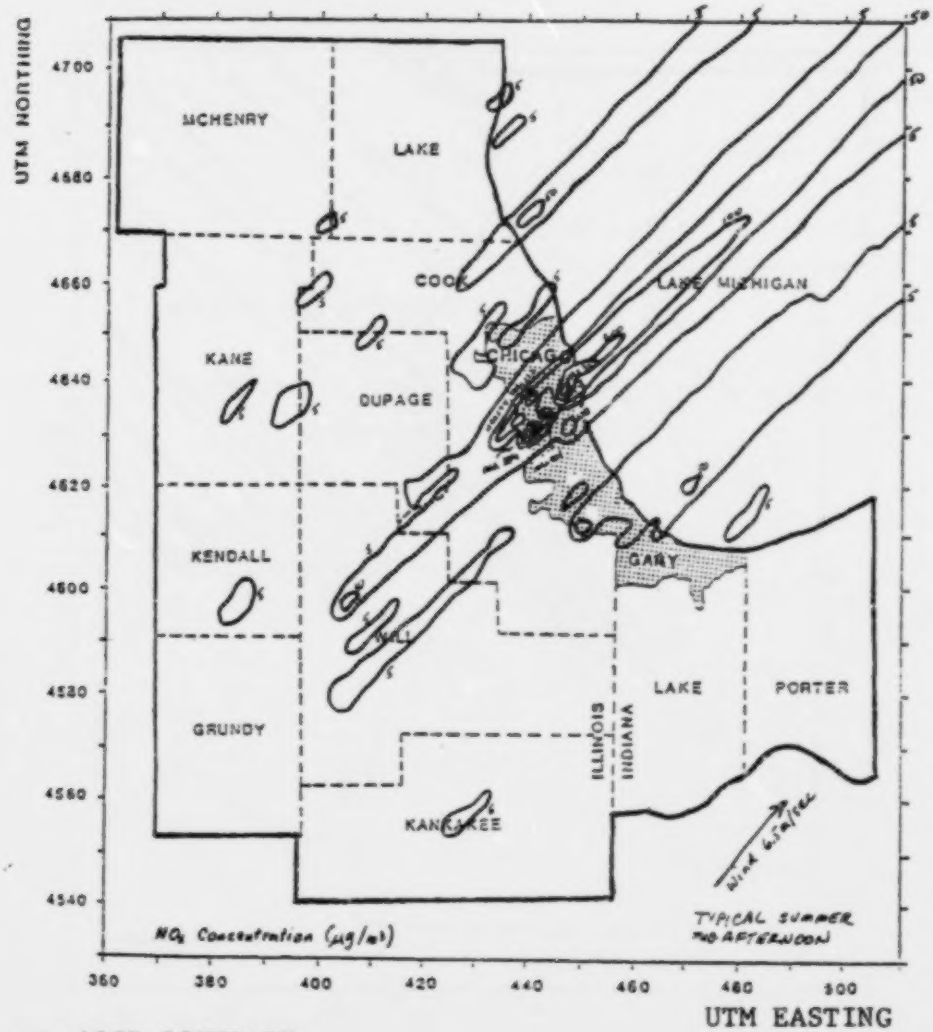
d. Modeling Procedures

Typical Case

Of the scenarios classed as "typical", the summer mid-afternoon was found to have the maximum potential for producing point source interactions. This is because the prevailing south-westerly wind for this scenario parallels the direction of the Chicago barge canal, along whose banks are located many of the local industries as well as the two Joliet power plants.

Conditions which characterize the summer mid-afternoon scenario are the following: the power system, while peaking, is meeting a demand below the summer peak. Point sources are peaking, as are vehicular sources; area emissions are moderate. The NO_2/NO_x ratio is one-half. Detailed atmospheric conditions for this scenario were described in the previous section (IV.B.3.c.).

Separate one-hour NO_x concentration isopleths were produced for the power plants and combustion turbines, and the large point sources. These are shown in Figures 14 and 15.



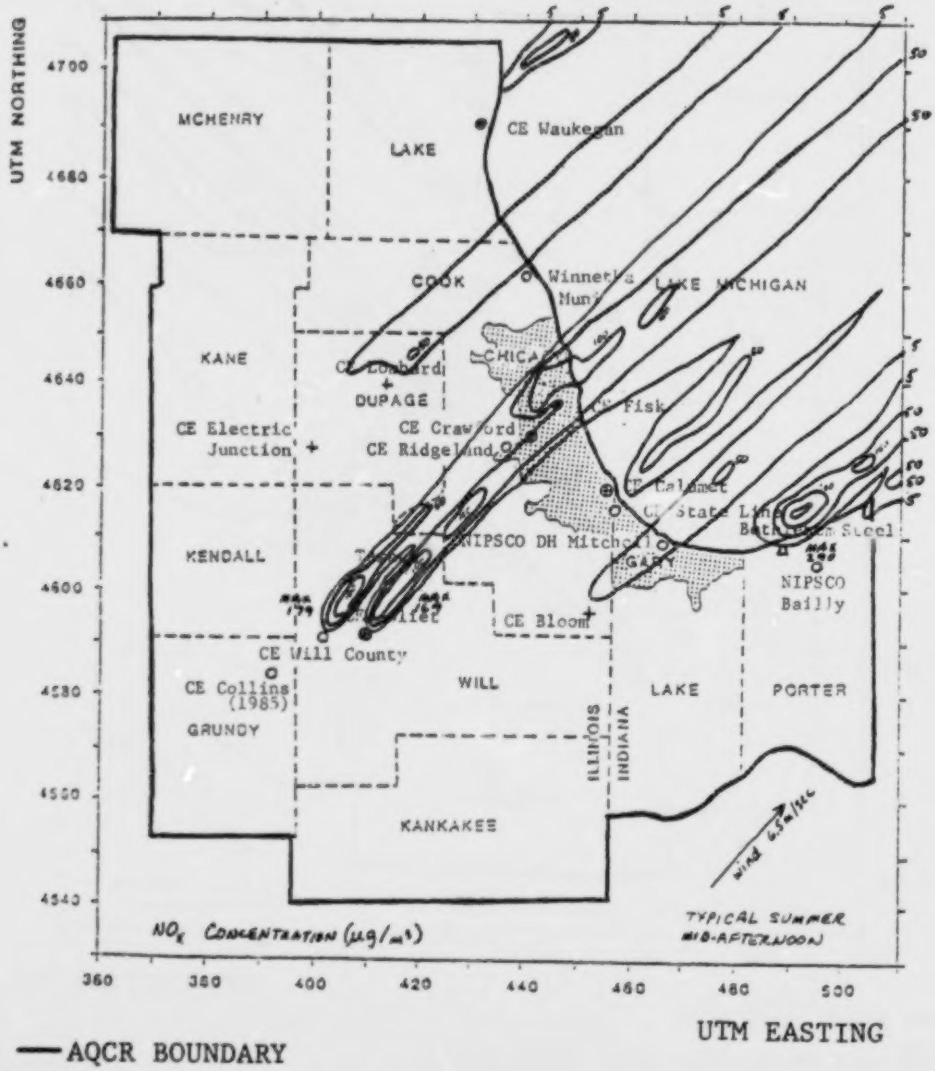
—— AQCR BOUNDARY

▨ INCORPORATED AREA BOUNDARY

- - - COUNTY BOUNDARIES

Isopleths at 5, 50, 100, 200, 300, 400 $\mu g/m^3$ worst concentration at (444,4634) = 461 $\mu g/m^3$

Figure 14. One-Hour Average NO_x Concentrations ($\mu g/m^3$) Power Plants - Summer Mid-Afternoon -- Typical



— AQCR BOUNDARY

▨ INCORPORATED AREA BOUNDARY

- - - COUNTY BOUNDARIES

Isopleths at 5, 50, 100, 200, µg/m³ worst concentration at (481,4615) = 290 µg/m³

○ UTILITY FOSSIL-FUELED STEAM PLANT

+ UTILITY COMBUSTION TURBINE PLANT

Δ NON-UTILITY FOSSIL-FUELED STEAM PLANT

Figure 15. One-Hour Average NO_x Concentrations (µg/m³) Large Point Sources - Summer Mid-Afternoon -- Typical

Worst Case Modeling

Worst case modeling, as defined in the previous section (IV.B.3.c.), is an attempt to maximize groundlevel concentrations of NO_x from large point sources. The NO_x emission rates, and the meteorological conditions which define the three worst case scenarios were also described. In a more quantitative fashion the meteorological conditions can be expressed as:

Summer Mid-Afternoon - Unstable

Stability class: B
Temperature: 80°F
Wind speed: 9 K
Mixing depth: 800 m

Summer Mid-Morning - Limited Mixing

Stability class: C
Temperature: 70°F
Wind speed: 5 K
Mixing depth: Nighttime effective stack height, 300 m or less.

Winter Mid-Morning - Limited Mixing

Stability class: C
Temperature: 20°F
Wind speed: 5 K
Mixing depth: Nighttime effective stack height, 300 m or less.

Receptor Selection and Modeling Methodology

The object of worst case modeling is to compute the maximum ground level NO_x concentration produced by large point sources, which in the current study, are the power plants. If a power plant can be treated as an isolated point source, then the maximum impact occurs at a distance which is determined essentially by the meteorological conditions. Furthermore, this distance is independent of the wind direction, and for the three worst case scenarios modeled it never exceeds four kilometers.

However, power plants are normally surrounded by other point and area sources, whose contribution at the point of maximum power plant impact must also be determined. Since these other sources are not uniformly distributed, their contribution to the NO_x concentration will be different for each wind direction. The cost in computer time to determine which particular wind direction produces the greatest contribution from this non-power plant component, for each of the power plants modeled, would be prohibitive.

The following procedure was, therefore, adopted. Four separate modeling runs, with the wind blowing from the North, South, East, and West, were made for the other point sources, the vehicular area sources, and the other area sources. For each of the four runs a single receptor was placed at the downwind distance where the maximum power plant concentration is found. In this fashion the maximum power plant impact for each of the four cardinal wind directions was determined. While this procedure does not provide the maximum concentration for every wind direction, it should, for the purposes of this study, adequately reflect the variations in the ambient worst case NO_x concentration that can be expected when the wind direction changes.

Modeling of Single Point Sources

Using the 1975 emission rates, downwind one-hour NO_x concentration curves were generated for all power plants and any associated combustion turbines for each of the three worst case scenarios. These curves, in turn, were used to determine the maximum power plant NO_x concentration C_{max} ($\mu g/m^3$) and the corresponding maximum impact distance R_{max} (Km). Then, in accordance with the procedure previously outlined, the contribution from the 537 point sources, the 640 vehicular area sources, and the 640 other area sources were determined with the wind blowing from the North, South, East, and West.

The results are given in Appendix J. Because Combustion Turbines are not amenable to current control strategy, their impacts have been tabulated separately. Changing the NO_x concentration but keeping the same meteorological conditions will change C_{max} in the same ratio as the emissions, but will not affect R_{max}. This feature permits us to derive the impacts for 1985 by scaling the 1975 results in accordance with the projected mass emission rates for NO_x. The results for 1985 are also contained in Appendix J.

Interactions Between Point Sources

A map of power plant locations in the AQCR is shown in Figure 12. Extensive preliminary modeling has shown that under high loadings, significant plume interactions exist among all the plants. In particular, within the following groups of plants, there are strong interactions:

- Bethlehem Steel, Bailly
- Calumet, State Line, Mitchell
- Ridgeland, Crawford, Fisk
- Collins, Will County, Joliet, Texaco

In addition, modeling has shown that the last three groups interact to some degree.

Table 13 gives the UTM coordinates of each plant, and of the point of highest concentration due to the interaction. The contributions from all other upwind point and area sources were also determined. The results for 1975 and 1985 are shown in Appendix J. From the modeling results for single point sources it was known that Summer Mid-Morning would give the worst concentration; consequently, only that particular scenario was studied.

4. Discussion of Results

a. Typical Case

The aim of modeling the "typical" scenarios was to determine the extent and the degree with which the point sources of the Chicago AQCR interact. Modeling results are presented in the form of concentration isopleths where points of significant impacts appear as "hot" spots.

Figure 16 presents the modeling results for Summer Mid-Morning. A number of features are of interest. First, power plant and point source isopleths are spatially separated and do not exhibit significant overlapping. Power plant plume interactions can and do occur. The isopleths centered on the 570 $\mu g/m^3$ "hot" spot are the result of an interaction between the Bailly, Bethlehem, and Mitchell Power Plants. It should also be noted that the 50 $\mu g/m^3$ isopleth extends 70 Km in the downwind direction.

In contrast, the isopleths for Summer Mid-Afternoon exhibit so much overlapping that the results for the power plants and point sources were presented separately in Figures 14

TABLE 13. POWER PLANT INTERACTION GROUPS

		UTM	
Group I			
	Bethlehem Steel	488.5	4609.1
	Bailly	495.6	4606.9
	Worst Interaction Point	498.8	4605.9
Group II			
	Calumet	454.5	4618.0
	State Line	456.6	4617.3
	Mitchell	466.1	4609.6
	Worst Interaction Point	456.2	4612.9
Group III			
	Crawford	440.1	4630.8
	Fisk	445.7	4633.3
	Ridgeland	434.8	4628.9
	Worst Interaction Point	448.8	4634.7
Group IV			
	Will County	400.5	4590.4
	1/2 Way between Joliet 2 & 6 and Joliet 7 & 8	409.75	4590.95
	Worst Interaction Point	414.7	4591.2

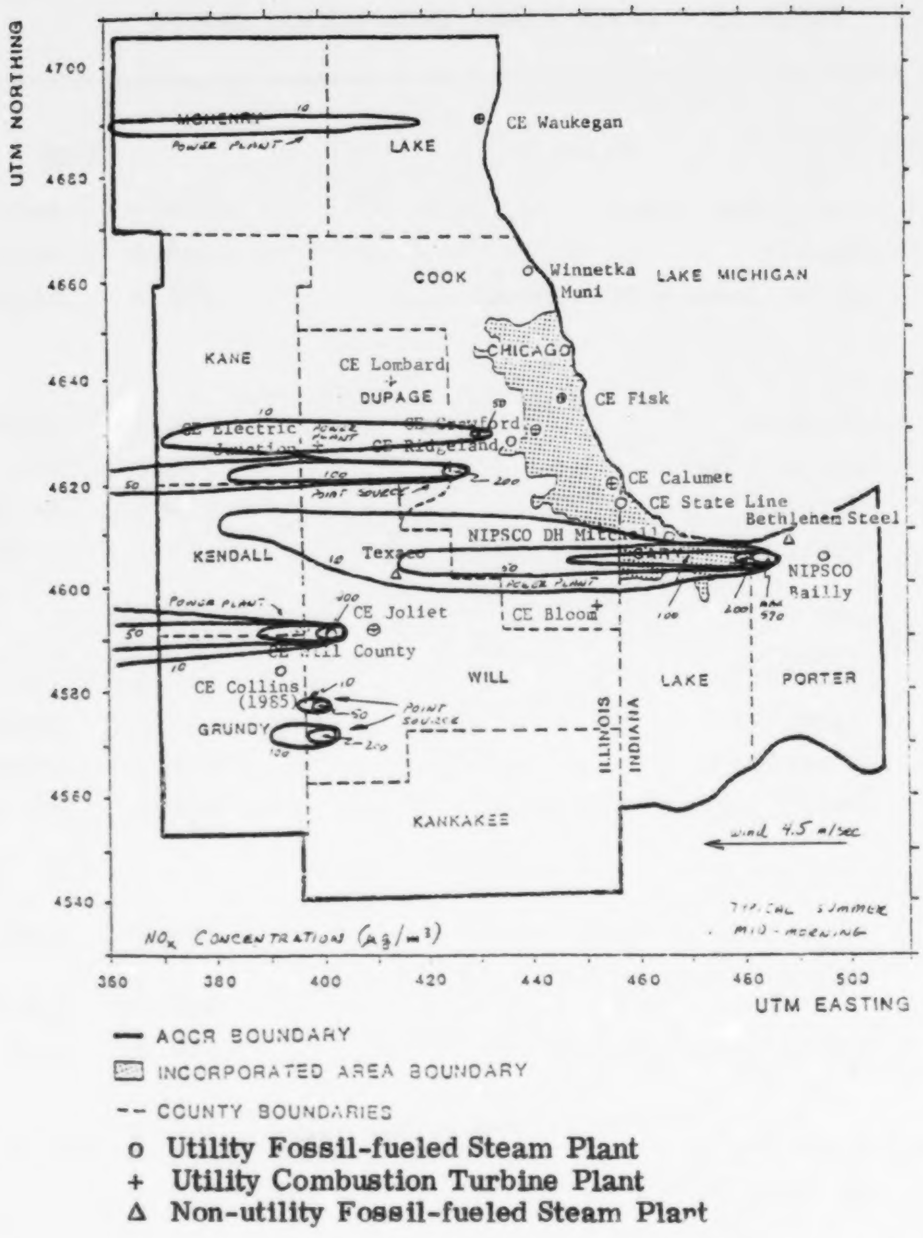


Figure 16. One-Hour Average NO_x Concentrations ($\mu g/m^3$) Power Plants and Large Point Sources - Summer Mid-Morning -- Typical

and 15, respectively. Significant plume interactions occur for both power plants and point sources along a 70 Km line from Joliet to downtown Chicago. They are responsible for producing NO_x concentrations as high as 500 $\mu g/m^3$ in the downtown area and over Lake Michigan Northeast of the Loop.

The results for these two "typical" scenarios succinctly illustrate the degree and extent to which point sources may or may not interact, and the sensitivity of such interactions to external conditions such as source spacings and meteorological conditions.

However, of primary importance is that for "typical" conditions the maximum NO_x concentrations are on the order of 500-600 $\mu g/m^3$. These are significantly less than the maximum impacts produced by power plants alone during "worst" case conditions. It is for this reason that the "typical" scenarios were assigned a secondary role in this study, and why the major emphasis was given to "worst" case modeling.

b. Evaluation of Worst-Case Results

Worst-case modeling for power plants in the Chicago AQCR yielded the results in Appendix J. These results are summarized in Figures 17 through 19; they reflect contributions to ambient NO_x concentration by source type. Total one-hour worst-case ambient NO_2 concentrations from these figures are summarized in Tables 14 and 15; they reflect total NO_2 concentrations where the power plant contribution was of maximum magnitude. In all but one case (Winnetka - 1985), these results also reflect the absolute maximum total concentrations of NO_2 found in the study and all occur during the Summer AM Scenarios. In the Winnetka - 1985 case, the Winter AM Scenario gave the worst absolute maximum concentration, but the difference

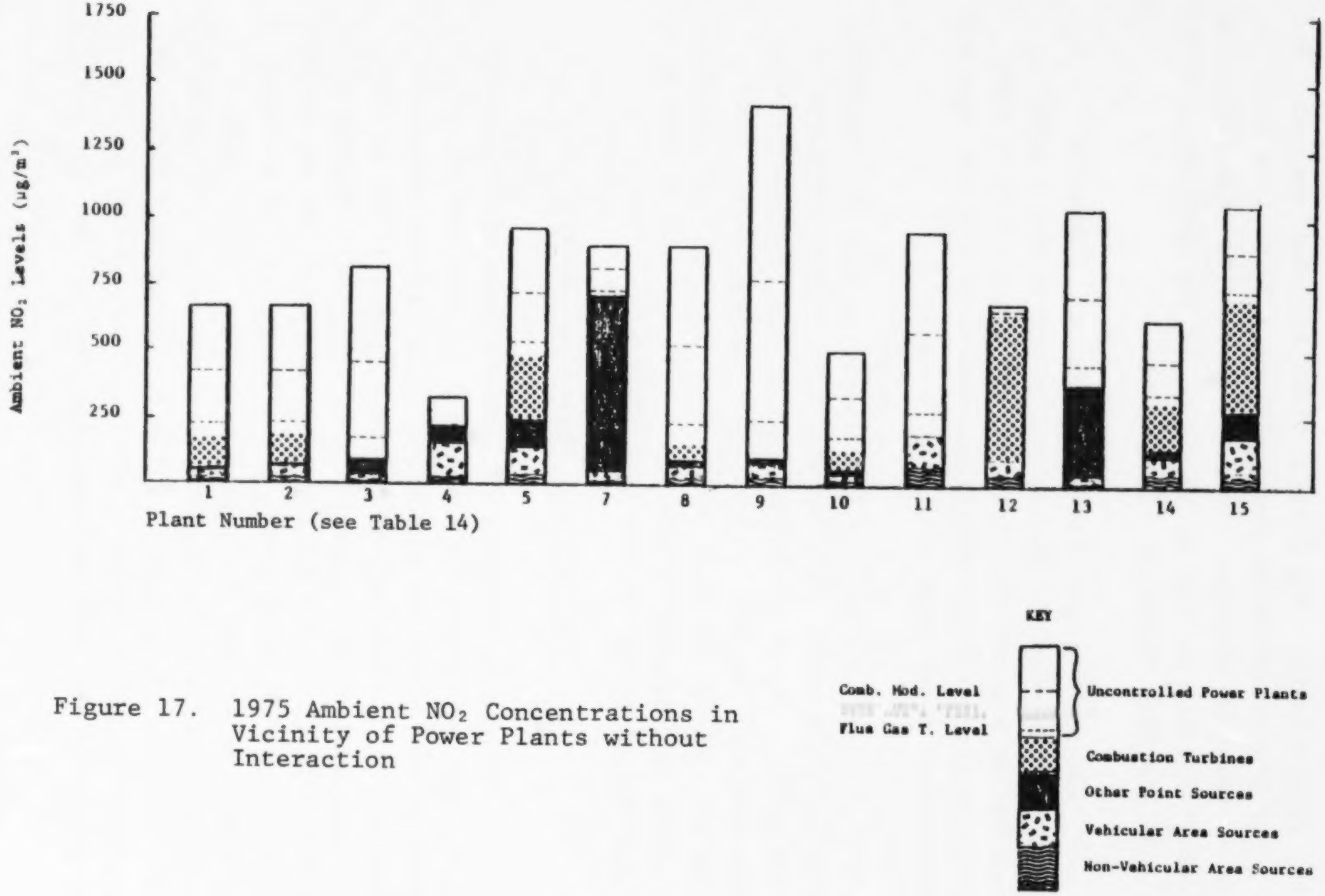


Figure 17. 1975 Ambient NO_2 Concentrations in Vicinity of Power Plants without Interaction

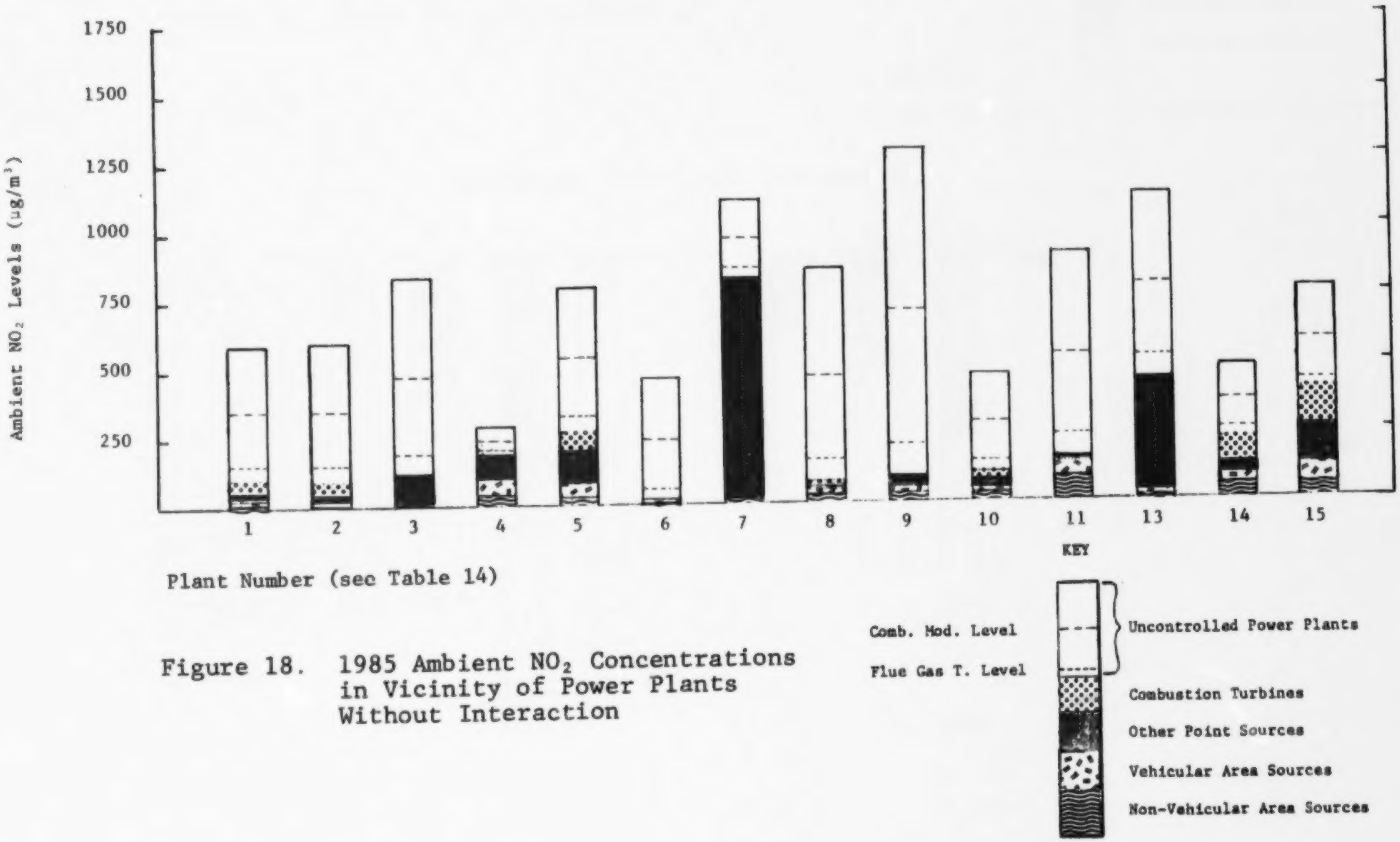


Figure 18. 1985 Ambient NO_2 Concentrations in Vicinity of Power Plants Without Interaction

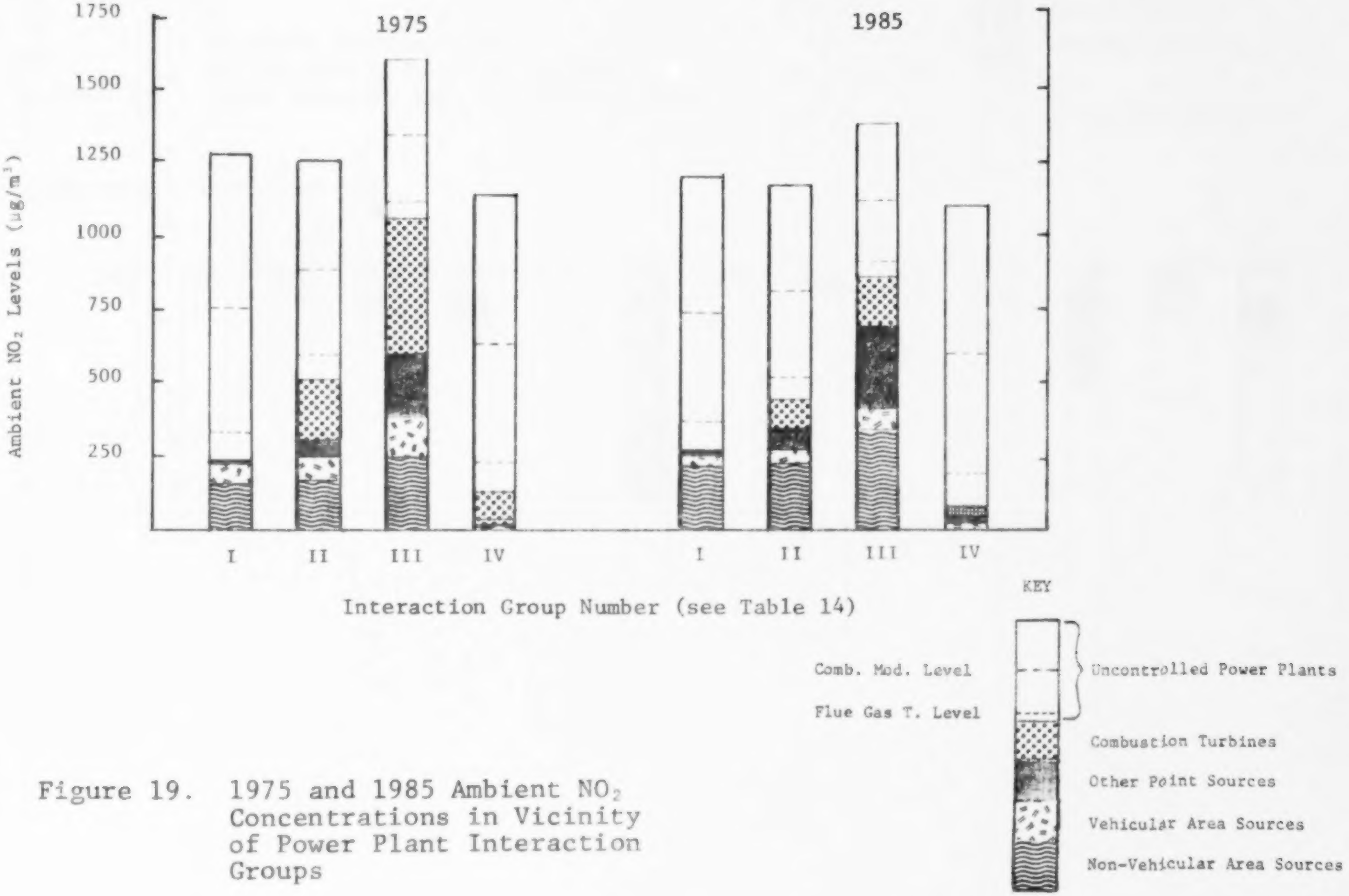


Figure 19. 1975 and 1985 Ambient NO_2 Concentrations in Vicinity of Power Plant Interaction Groups

TABLE 14. WORST CASE GROUNDLEVEL NO_2 CONCENTRATIONS PRODUCED BY INDIVIDUAL POWER PLANTS AND INTERACTIONS CASES - 1975

PLANT	CONCENTRATION WITHOUT CONTROLS ($\mu g/m^3$)	CONCENTRATION WITH CM ($\mu g/m^3$)	COST-CM+	CONCENTRATION WITH FGT ($\mu g/m^3$)	COST FGT+
1. Joliet 2 & 6	649	405	$0.7M	210	$4-34M
2. Joliet 7	668	413	$2.0M	209	$12-92M
3. Will County	801	446	$1.7M	162	$10-79M
4. Winnetka	313	264	$0.1M	224	$0.5-4M
5. Waukegan	974	712	$1.4M	502	$8-66M
6. Collins*	---	---	---	---	---
7. Texaco	886	351	$0.04M	277	$0.3-2M
8. Bailly	892	515	$1.1M	213	$6-49M
9. Bethlehem Steel	1410	745	$2.4M	229	$14-108M
10. Mitchell	499	319	$0.9M	175	$5-42M
11. Stateline	941	565	$.15M	265	$9-69M
12. Calumet	692	666	$0.2M	646	$1-9M
13. Ridgeland	1021	685	$1.2M	346	$7-54M
14. Crawford	624	470	$1.2M	346	$7-54M
15. Fisk	1050	860	$0.8M	708	$5-38M
GROUP I**	1278	759	$3.4M	343	$20-157M
GROUP II	1255	883	$2.6M	585	$15-120M
GROUP III	1595	1325	$3.2M	1110	$18-147M
GROUP IV	1138	632	$4.5M	338	$26-205M

*Did not exist in 1975.
+1977 Dollars
M-Million
**See Table 13 for the definition of these interaction groups.

TABLE 15. WORST CASE GROUNDLEVEL NO_2 CONCENTRATIONS PRODUCED BY INDIVIDUAL POWER PLANTS AND INTERACTION CASES - 1985

PLANT	CONCENTRATION WITHOUT CONTROLS ($\mu g/m^3$)	CONCENTRATION WITH CM ($\mu g/m^3$)	COST-CM+	CONCENTRATION WITH FGT ($\mu g/m^3$)	COST FGT+
1. Joliet 2 & 6	575	331	$0.7M	136	$4-34M
2. Joliet 7	593	338	$2.0M	134	$12-92M
3. Will County	824	469	$1.7M	185	$10-79M
4. Winnetka	288	239	$0.1M	199	$0.5-4M
5. Waukegan	794	532	$1.4M	322	$8-66M
6. Collins	459	236	$4.5M	57	$25-204M
7. Texaco	1108	1015	$0.04M	941	$0.3-2M
8. Bailly	849	471	$1.1M	169	$6-49M
9. Bethlehem Steel	1277	686	$2.4M	214	$14-108M
10. Mitchell	472	292	$0.9M	148	$5-42M
11. State Line	904	528	$1.5M	225	$9-69M
12. Calumet*	---	---	---	---	---
13. Ridgeland	1113	777	$1.2M	508	$7-55M
14. Crawford	484	363	$1.0M	266	$6-45M
15. Fisk	766	576	$0.8M	424	$5-38M
GROUP I**	1301	787	$3.4M	371	$20-157M
GROUP II	1172	810	$2.5M	520	$14-112M
GROUP III	1377	1120	$3.0M	915	$17-138M
GROUP IV	1099	593	$4.5M	189	$26-205M

*Retired
+1977 Dollars
M-Million
**See Table 13 for the definition of these interaction groups.

in values between the table and this case are probably not measurable with instruments. The tables also reflect costs given by Aerotherm as \$1.75/KWe for 50 percent NO_x reduction through retrofit combustion modification (CM) and by EPA as \$10-80/KWe (\$30 avg.) for 90 percent NO_x reduction achieved through flue gas treatment (FGT). The following points must be noted from these tables:

1. The effect of control technology is severely restricted by certain site-specific factors, such as proximity to large point sources, etc. No single control technology applied uniformly achieves uniform results.

2. In some cases, controls must be applied to sources other than power plants to achieve significant reductions in ambient NO_2 concentration.

Thirteen power plants and large point sources were considered in this study. Table 16 gives the number of plants which require CM or FGT controls in order to meet various ambient NO_x levels, assuming no interaction among plants. Table 17 gives the number of plants requiring controls assuming interactions. The results in Table 17 assume that identical control technology is applied to all plants in the same group in order to achieve the required ambient reduction. This assumption is conservative since it does not take into account any attempt to investigate an optimum strategy mix for an interaction group. Such analysis was beyond the scope of this project.

Tables 18 and 19 provide cost estimates for the controls required to meet the various ambient levels for the independent and interaction cases, respectively. The costs shown

TABLE 16. NUMBER OF PLANTS REQUIRING NO$_x$ CONTROLS TO MEET AMBIENT LEVELS WITHOUT INTERACTION

Ambient Levels (μg/m^3)	1975		1985	
	CM	FGT	CM	FGT
1000	3	0	3	0
250	9	0	5	1(1)
500	8	4(1)*	5	3(1)
250	1	13(5)	5	9(3)

*The number in ( ) indicates the number of plants which are in areas where additional controls on other sources will be required to meet ambient levels.

TABLE 17. NUMBER OF PLANTS REQUIRING NO$_x$ CONTROLS TO MEET AMBIENT LEVELS WITH INTERACTION

Ambient Levels (μg/m^3)	1975		1985	
	CM	FGT	CM	FGT
1000	8	2	5	3
750	7	6(3)*	5	6(4)
500	1	12(3)	4	8(4)
250	1	13(7)	1	12(6)

*The number in ( ) indicates the number of plants which are in areas where additional controls on other sources will be required to meet ambient levels.

TABLE 18. COST OF LARGE POINT SOURCE CONTROLS REQUIRED TO MEET AMBIENT LEVELS WITHOUT INTERACTIONS IN MILLIONS OF 1977 DOLLARS

Ambient Level ($\mu g/m^3$)	1975		1985	
	CM	FGT	CM	FGT
1000	$ 3.8	NR	$3.64	NR
750	$10.34	NR	$7.9	$ 0.3-2*
500	$ 9.14	$28-221*	$6.5	$21.3-65*
250	$ 0.1	$137.688*	$8.1	$65.3-511*

*Costs of additional controls on other sources not included but required to meet standard.

NR-Not Required.

TABLE 19. COST OF LARGE POINT SOURCE CONTROLS REQUIRED TO MEET AMBIENT LEVELS WITH INTERACTIONS IN MILLIONS OF DOLLARS

Ambient Level ($\mu g/m^3$)	1975		1985	
	CM	FGT	CM	FGT
1000	$10.5	$18-147	$5.9	$17-138
750	$ 7.5	$33-267*	$7.9	$31-250*
500	NS	$79-629*	$4.5	$51-407*
250	NS	$79-629*	NS	$77-612*

*Costs of additional controls on other sources not included but required to meet standard.

NS-Not sufficient; plants require FGT

in Table 18 and 19 are very rough estimates based upon the "rule-of-thumb" formulas from Aerotherm and EPA described previously and can be expected to vary substantially in any practical control application.

c. Isolated Plant Siting

In order to address the impact of the current trend in power plant siting on projected NO_2 levels, the case of a large isolated power plant was investigated. Commonwealth Edison's Powerton Station was used as a hypothetical example of such a plant.

CE's Powerton Station is a large (1700 MWe) coal-fired plant located near Pekin, Illinois, far from any large urban complex. Its location is more indicative of the siting of new large power plants. This plant contains two 850 MWe cyclone units firing medium sulfur Illinois coal. For this example, cyclones and pulverized dry bottom boilers of identical size were considered; emissions estimates based on FPC form 67 and AP-42 data for both cases are in Table 20. For the three scenarios modeled, concentrations of NO_x and NO_2 in Table 21 were found.

TABLE 20. ESTIMATED MAXIMUM EMISSIONS FOR ISOLATED LARGE COAL PLANT

Case	Maximum NO_x Emission Rate
Cyclone	41,081 lb/hr
Dry Botton, Pulverized	13,445 lb/hr

TABLE 21. EXPECTED WORST CASE GROUND-LEVEL CONCENTRATIONS FROM ISOLATED LARGE COAL PLANT

Type	Scenario	NO_x (μg/m³)	NO_2 (μg/m³)
Cyclone	Summer AM	523	262
	Summer PM	2317	1159
	Winter AM	2317	579
Dry Bottom, Pulverized	Summer AM	171	86
	Summer PM	758	379
	Winter PM	758	190

As can be seen from this table, the cyclone unit does not comply with any of the four standards examined. However, combustion modification at a cost of $3 million would bring the plant essentially into compliance with all standards except 250 μg/m³, which would require flue gas treatment at costs between $17 million and $136 million. On the other hand, if a dry bottom boiler were used, everything else being equal, the unit would be in compliance with no controls for all standards except 250 μg/m³, which requires combustion modification. This analysis indicates that flue gas treatment would be beneficial probably on most cyclone units and on certain units in heavily urbanized areas where need could be proven. Otherwise, combustion modification will allow compliance with most, if not all, standards studied. In light of the high costs associated with flue gas treatment and the reductions achieved with the less expensive combustion modification, it is expected that combustion modification would have the most beneficial overall effect, with flue gas treatment being applied only in a few cases. However, there are many uncertainties and limitations regarding both combustion modification and flue gas treatment technologies which may become overriding considerations when determining a control strategy.

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APPENDIX A

SELECTED CONVERSION FACTORS

APPENDIX A

SELECTED CONVERSION FACTORS

New Units	Equal	Old Units	Multipled By
Joules		Million BTU (MMBTU)	1.054×10^9
Metric Tons/ Year		Tons/Year	0.907
m/sec		knots	0.514
g/sec		lb/hour	0.125
m^3		Thousand Cubic Feet (MCF)	28.3
m/sec		mph	0.447
kilometer		mile	1.609
g/joule		lb/MMBTU	4.304×10^{-7}
kPa		psia	0.143

APPENDIX B

AREA SOURCE GRIDDING PROCEDURE

I. INTRODUCTION

The purpose of this appendix is to describe the procedure employed for allocating area source air pollution emissions to grids that form the input basis to air pollution dispersion models. The basic approach is to divide the total area being considered (whether it be a city, county, air quality control region, or whatever) into subareas that can be used to partition the total area emissions. The idea is to account for the spatial distribution of area source emissions so that air pollution dispersion models can make reasonable predictions of the distribution of pollutant concentrations.

II. METHODOLOGY SUMMARY

The steps to set up the input gridding procedure are as follows:

1. Define the boundaries of the total area being considered.

2. Specify the apportionment parameter (e.g., population, miles of road, number of houses, etc.) to be used to distribute emissions throughout the total area.

3. Determine the subareas (e.g., census tracts, traffic zones, counties, etc.) for which measures of the apportionment parameter selected in Step 2 are known. The relative size of the individual subareas chosen will, in general, depend upon the resolution required in the air quality impact analysis.

4. Determine the total emissions to be distributed throughout the total area specified in Step 1.

5. Allocate to each subarea (from Step 3) the appropriate fraction of the total emissions (from Step 4) as determined by the apportionment parameter.

6. Define the input grid network for the dispersion model, and construct an overlay

from this grid which can be placed over
a map of the subareas (from Step 3).

When these six steps have been accomplished, gridding calculations can be performed which will assign a total pollutant emission rate to each model input grid.

III. METHODOLOGY DESCRIPTION

The procedures and calculations involved in area source gridding can best be described by means of an example. We will take a hypotehtical case and work through the entire procedure from set-up to calculations.

Our hypothetical problem is to apportion the mobile hydrocarbon emissions of Noname County to area source emissions grids which can be input to an air pollution dispersion model. The steps outlined in Section II are performed as follows:

1. Define total area boundaries -

   Prepare Figure 1 which is a map of Noname County with appropriate Universal Transverse Mercater (UTM) coordinates included.

2. Specify apportionment parameter -

   We propose to use total vehicle miles travelled (VMT) to apportion mobile hydrocarbon emissions. That is, we think that the spatial distribution of VMT is a good approximation of the spatial distribution of mobile hydrocarbon emissions.

3. Define subareas -

   Since we have a VMT count for each traffic zone in Noname County, and since the traffic zones provide about the resolution we need, we will use the traffic zones indicated in Figure 2 as our subareas.

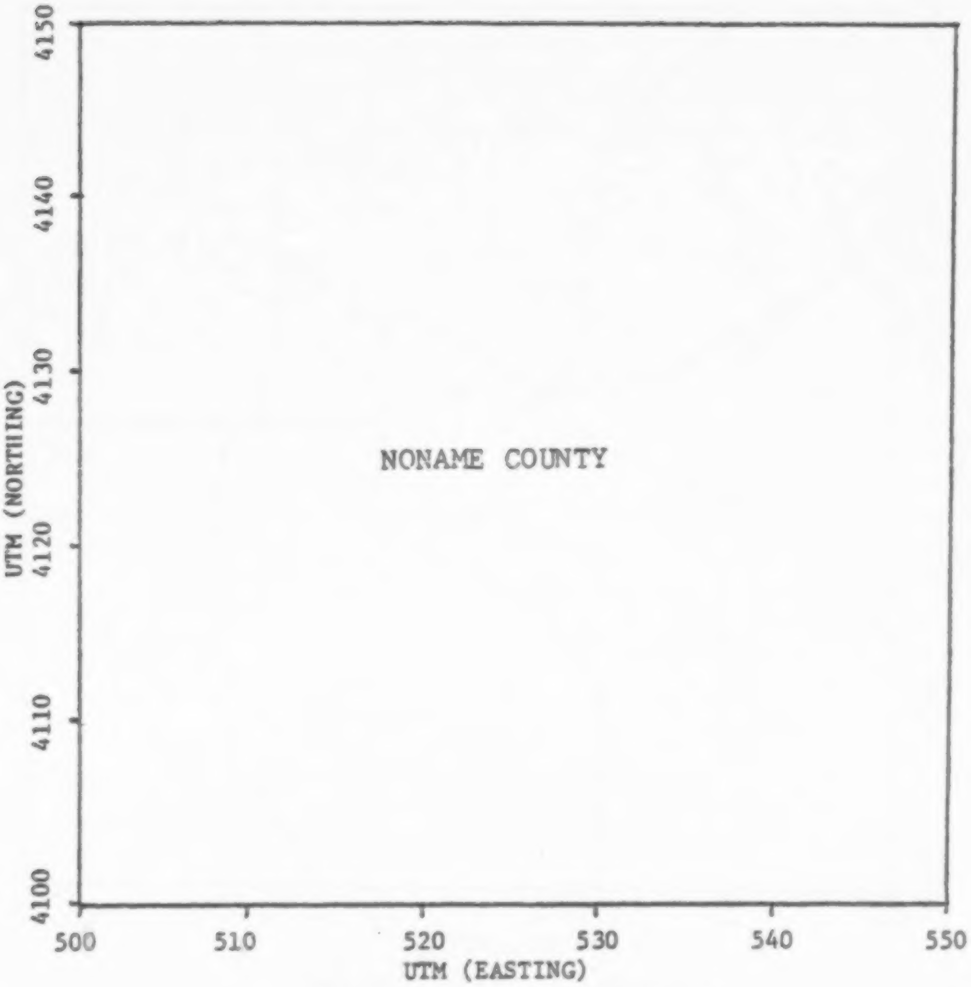

FIGURE 1. COUNTY BOUNDARIES

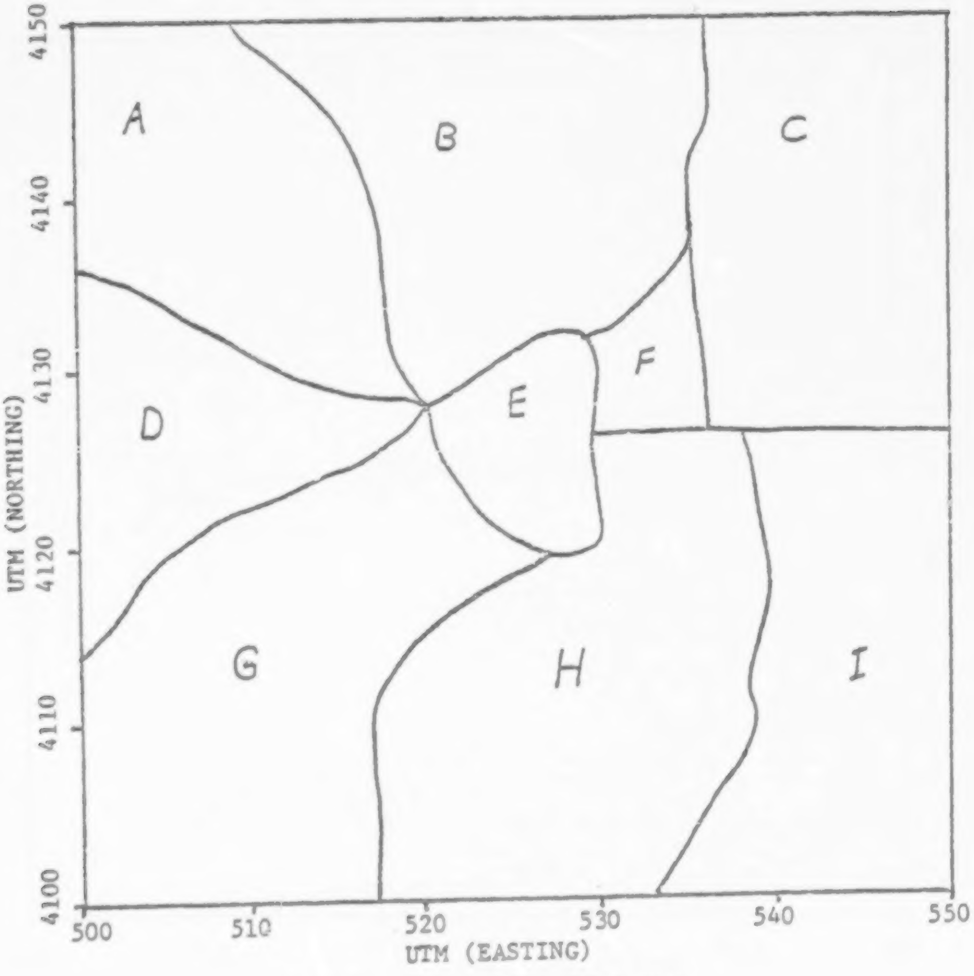

FIGURE 2. TRAFFIC ZONE MAP

4. Determine total emissions -

We are told, let's say, that the total mobile hydrocarbon emission rate in Noname County is 10,000 tons/year.

5. Allocate emissions to subareas -

Construct Table 1 which gives the emissions assigned to each subarea based upon the apportionment parameter. We are given the VMT counts in the second column. The third column is the fraction of county total VMT's in each zone. The fourth column entries are found by taking the fraction for each zone times the total county mobile hydrocarbon emissions.

In some cases, Table 1 may not be the format to use for subarea emission calculations. There may be cases where the emission factor varies from subarea to subarea. For example, if we wanted to account for a difference in vehicular speed, we might want to assign each traffic zone an average speed and incorporate this term into an emission factor. The emission factor, when scaled to the right units, could then be multiplied by the VMT count in each zone to get hydrocarbon emissions directly.

Regardless of the approach used, the end result from Table 1 should be to assign specific pollutant emissions to each subarea.

TABLE 1

SUBAREA EMISSIONS CALCULATIONS

Traffic Zone	10^3 VMT	VMT Fraction	Hydrocarbon Emissions (tons/year)
A	500	.091	910
B	800	.145	1450
C	300	.055	550
D	700	.127	1270
E	900	.164	1640
F	1000	.182	1820
G	700	.127	1270
H	400	.073	730
I	200	.036	360
TOTAL	5500	1.000	10,000

6. Define model input grid network -

We construct the grid network in Figure 3 which we feel offers the desired resolution to the dispersion model. Note that each grid is a square and that the width of the bigger squares is an integer multiple of the width of the smallest squares. (These are necessary conditions for most dispersion models.)

What is left now is to assign an emission rate to each grid in Figure 3 using the information obtained thus far. This will be done by allocating the emissions of each subarea to the grids that "cover" that subarea based upon what portion of the subarea is in each grid.

For example, look at traffic zone "D" in Figure 3. About 4/10 of D's area is covered by grid 8, about 1/10 by grid 19, and about 1/4 by each of grids 1 and 9. For zone "I", about 5/6 is in grid 22 and 1/6 in grid 14. For zone "E", about 3/10 is in each of grids 11 and 16, 2/10 in grid 10, and 1/10 in each of grids 5 and 15. That part of E in grid 20 can be disregarded. Similar divisions can be made for each of the remaining zones. Usually, these divisions can be made using best judgements and "eyeball" approximations, as is being done here. If a more exact analysis is required, a planimeter can be used. Regardless of the method used, it is important that the subarea fractions assigned to grids sum to one.

The division process continues until all subareas (zones) have been divided out into the grids. A table should be kept of this work, and it should be structured as shown in Table 2. Note that each grid and each subarea are accounted for in Table 2.

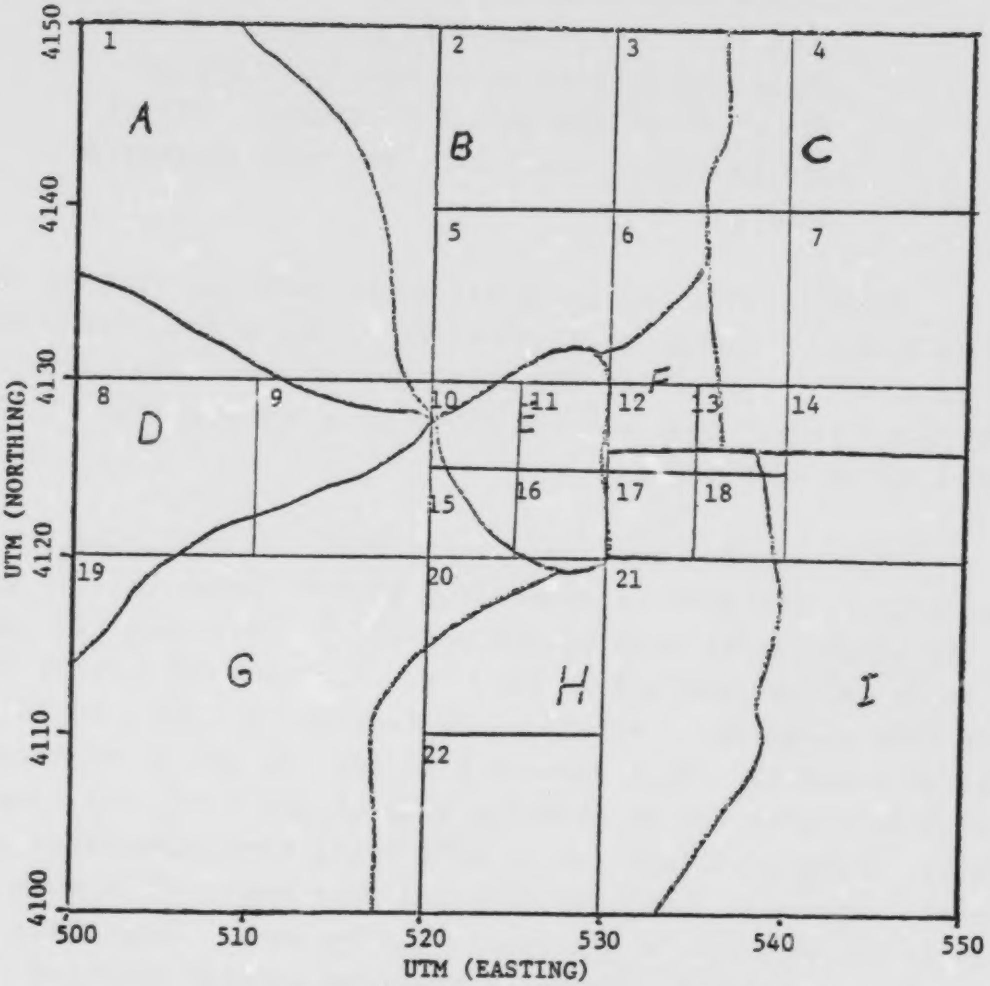

FIGURE 3. AREA SOURCE GRID OVERLAY

TABLE 2

WORKING TABLE FOR GRIDDING PROCEDURES

	Zones								
Grid	A	B	C	D	E	F	G	H	I
1	14/15	1/4		1/4					
2		1/4							
3		1/6	1/9						
4			3/10						
5		1/4			1/10				
6		1/12	1/9			1/2			
7			3/10						
8				4/10			1/45		
9	1/15			1/4			1/9		
10					2/10				
11					3/10				
12						4/10		1/40	
13			1/15			1/10		1/40	
14			1/9						1/6
15					1/10		1/18		
16					3/10				
17								1/16	
18								1/16	
19				1/10			34/45	1/10	
20							1/18	3/20	
21								3/8	5/6
22								2/10	
Total	1	1	1	1	1	1	1	1	1
Emissions	910	1450	550	1270	1640	1820	1270	730	360

Note also that the column (subarea) fraction totals are all equal to one. If any column does not sum to one, the total grid network emissions will be incorrect. The subarea emissions should be entered at the bottom of the table to facilitate the calculations which follow.

To compute the emissions for an individual grid, multiply the fraction in each zone column by the total zone emissions at the bottom of the zone column. Sum these products to get the total grid emissions. For example, from Table 2, we compute the emissions for grid 1 as follows:

$$14/15\ (910) + 1/4\ (1450) + 1/4\ (1270) = 1529.3$$

A similar calculation is performed for each grid.

Table 3 shows the final output from the procedure. Included in Table 3 are the UTM coordinates of the southwest corner of each square and the length of the square side. This information is required in the dispersion models. Table 3, then, will provide the person actually running the dispersion model program with the grid inputs he needs in order to exercise the model.

Rounding errors abound in a procedure like the one described here. Small errors in the total allocated emissions (±.1%) can be expected and should not cause problems. However, one needs to be aware of the rounding problem and be prepared to adjust some of the figures if greater accuracy is required.

TABLE 3

EMISSION GRIDDING RESULTS

GRID	UTM X	UTM Y	SIDE LENGTH (meters)	HYDROCARBON EMISSIONS (tons/year)
1	500	4130	20,000	1529.3
2	520	4140	10,000	362.5
3	530	4140	10,000	302.8
4	540	4140	10,000	165.0
5	520	4130	10,000	526.5
6	530	4130	10,000	1091.9
7	540	4130	10,000	165.0
8	500	4120	10,000	536.2
9	510	4120	10,000	519.3
10	520	4125	5,000	328.0
11	525	4125	5,000	492.0
12	530	4125	5,000	746.3
13	535	4125	5,000	236.9
14	540	4120	10,000	121.1
15	520	4120	5,000	234.6
16	525	4120	5,000	492.0
17	530	4120	5,000	45.6
18	535	4120	5,000	45.6
19	500	4100	20,000	1159.6
20	520	4110	10,000	180.1
21	530	4100	20,000	573.8
22	520	4100	10,000	146.0
Total				10000.1

APPENDIX C

AREA SOURCE EMISSION FACTORS

(Selected pages from Volumes II and IV of NADB's AEROS Manual)

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NEDS AREA SOURCE EMISSION CALCULATION PROCEDURES

The NEDS procedure for computer calculation of emissions that has been used to date is quite simple for most source categories. The procedure is:

$$\text{Emissions (tons/yr)} = \frac{\text{Source Category Activity Level} \times \text{Multiplier} \times \text{Emission Factor}}{2000}$$

The source category activity levels are the values given for each source category on the area source form. For example to calculate particulate emissions for residential on-site incineration, if the value coded on the area source form is 2400.

$$\text{Emissions (tons/yr)} = \frac{2400 \times 10 \times 30}{2000} = 360$$

Sulfur and ash parameters for fuels are included in the emission factors when appropriate.

The calculation procedure for motor vehicles is more complex and is described below. Emission factors for use with each area source category are also given in the following table. These emission factors are updated as new data becomes available. The emission factors shown are those that are used for 1973 area source calculations.

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AREA SOURCE EMISSION FACTORS

CATEGORY	MULTIPLIER	PART	SOX	NOX	HC	CO
Anthractie Coal						
Residential	10	10.000	36.800S	3.000	2.500	90.000
Commercial & Institutional	10	2.000A	38.500S	10.000	0.200	6.000
Industrial	10	2.000A	38.500S	15.000	0.200	2.000
Bituminous Coal						
Residential	10	20.000	38.000S	3.000	20.000	90.000
Commercial & Institutional	10	5.800A	38.000S	9.200	2.000	7.200
Industrial	10	13.000A	38.000S	15.000	1.000	2.000
Distillate Oil						
Residential	10	10.000	144.000S	12.000	3.000	5.000
Commercial & Institutional	10	15.000	144.000S	60.000	3.000	4.000
Industrial	10	15.000	144.000S	60.000	3.000	4.000
Residual Oil						
Residential	10	23.000	159.000S	40.000	3.000	4.000
Commercial & Institutional	10	23.000	159.000S	50.000	3.000	4.000
Industrial	10	23.000	159.000S	60.000	3.000	4.000
Natural Gas						
Residential	10	10.000	0.600	80.000	8.000	20.000
Commercial & Institutional	10	10.000	0.600	120.000	8.000	20.000
Industrial	10	10.000	0.600	180.000	3.000	17.000
Wood						
All Categories	100	25.000	1.500	10.000	20.000	20.000
Process Gas						
Industrial	10	20.000	2.000	230.000	30.000	Neg.
On-Site Incineration						
Residential	10	32.000	0.500	1.000	90.000	270.000
Commercial	100	8.000	2.500	3.000	5.000	11.500
Industrial	100	8.000	2.500	3.000	5.000	11.500
Open Burning						
Residential	100	16.000	1.000	6.000	30.000	85.000
Commercial	100	16.000	1.000	6.000	30.000	85.000
Industrial	100	16.000	1.000	6.000	30.000	85.000
vaporation						
Solvent	1	0.000	0.000	0.000	2000.000	0.000
Gasoline Marketing	100	0.000	0.000	0.000	22.000	0.000

Unpaved Roads	1	NA	0.0	0.0	0.0	0.0
Unpaved Airstrips	1	NA	0.0	0.0	0.0	0.0
Construction	1	NA	0.0	0.0	0.0	0.0
Misc. Wind Erosion	1	NA	0.0	0.0	0.0	0.0
Land Tilling	1	NA	0.0	0.0	0.0	0.0
Forest Wildfires	quan.	17.0	Neg.	4.0	24.0	140.0
Managed Burning	quan.	17.0	Neg.	2.0	20.0	60.0
Agricultural Burning	quan.	17.0	Neg.	2.0	20.0	100.0
Frost Control	days fir.	0.2	0.1	0.0	43.0	22.0
Structure Fires	1	108.0	0.2	9.4	28.0	244.0
Off Highway						
Gasoline	1	10.7	5.6	122.0	344.0	3900.0
Diesel	10	33.3	29.8	369.0	40.4	104.0
Rail Locomotive	10	25.0	57.0	370.0	94.0	130.0
Aircraft						
Military	100	19.9	3.8	9.56	46.3	49.7
Civil	10	0.569	0.113	0.514	2.520	14.40
Commercial	10	1.79	2.56	25.2	33.1	68.30
Vessels						
Bituminous Coal	10	20.0	50.0	3.0	20.0	90.0
Distillate Oil	10	24.0	30.0	224.0	58.8	78.4
Residual Oil	10	19.3	286.0	41.8	2.9	1.4
Gasoline	1	Neg.	6.3	27.4	931.0	2960.0

A = Fuel ash content
S = Fuel sulfur content
NA = Not available, national level emission factors not appropriate
Neg. = Emissions are negligible, but not necessarily zero.

All final products should be divided by 2000 (lb/ton) to get emissions into proper consistent units of tons.

MOTOR VEHICLE EMISSION CALCULATIONS

The first step in estimating motor vehicle emissions is to esbablish the mileage ratios for the different classes of vehicles:

1) Multiply gasoline fuel for light vehicles times 1000 times 13.6 (mpg)
2) Multiply gasoline fuel for heavy vehicles times 1000 time 3.4 (mpg)
3) Multiply diesel fuel for heavy vehicles times 1000 5.0 (mpg).

Add the products - SUM of vehicle miles traveled. (M_T)

Obtain ratio of vehicle milt total for category of vehicle.

$R_{LD} = \frac{(1)}{SUM} = .$______

$R_{HDG} = \frac{(2)}{SUM} = .$______

$R_{HDD} = \frac{(3)}{SUM} = .$______

If any measured vehicle miles are filled in, proceed as follows:

Then multiply each ratio from above times each "Measured Vehicle Miles" category, times appropriate emission factor, i.e.

Limited Access Road - miles (M_L) times 10,000 times R_{LD} times appropriate emission factor plus M_L times 10,000 R_{HDG} times appropriate emission factor plus M_L times 10,000 R_{HDD} times appropriate emission factor.

$\frac{1}{453.6 \quad 2000}$ times sum is the emissions for limited access roads in tons______

Suburban Roads - miles (M_S) times 10,000 R_{LD} times appropriate emission factor plus M_S times 10,000 R_{HDG} times appropriate emission factor.

$\frac{1}{453.6 \times 2000}$ x sum is the emissions for suburban roads in tons_______.

Urban Roads - miles (Mu) times 10,000 R_{LD} times appropriate emission factor plus Mu times 10,000 times R_{HDD} times appropriate emission factor.

$\frac{1}{453.6 \times 2000}$ x sum is the emissions for urban roads in tons__________.

If no measured vehicle miles are filled in, proceed as follows:

Sum the products (1), (2), (3) as determined previously (above) to obtain total miles traveled (M_T).

Determine the rural and urban mileage breakdown:

P_U = Density code* divided by 10

$P_R = 1.0 - P_U$

To calculate emissions, multiply the vehicle mile ratio (R_{LD}, R_{HDG}, R_{HDD}) times the total miles traveled (M_T) times the rural or urban factor (P_R or P_U) times the appropriate emission factor, i.e.,

---

*9 is used if value is mission and condition flagged.

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Rural Roads - M_T times R_{LD} times P_R times appropriate emission factor plus M_T times R_{HDG} times P_R times appropriate emission factor plus M_T times R_{HDD} times P_R times appropriate emission factor.

$\frac{1}{(2000)(453.6)}$ times sum is emissions from rural roads in tons ________.

Urban Roads - M_T times R_{LD} times P_U times appropriate emission factor plus M_T times R_{HDG} times P_U times appropriate emission factor plus M_T times R_{HDD} times P_U times appropriate emission factor.

$\frac{1}{(453.6)(2000)}$ times sum is emissions from urban roads in tons________.

NOTE: Using this second method Limited Acess and Suburban road emission will be assumed zero . . .

Add above sums for emission total for motor vehicles in tons.

FACTORS FOR AREA SOURCE EMISSIONS FROM MOBILE SOURCES - 1973

CATEGORY	PART	SOX	NOX	HC	CO
Limited Access Roads					
Light Duty - Gasoline	0.54	0.14	5.06	6.16	29.9
Heavy Duty - Gasoline	0.95	0.36	11.3	22.3	113.1
Heavy Duty - Diesel	2.0	2.8	27.6	2.44	7.46
Rural Roads					
Light Duty - Gasoline	0.54	0.14	4.9	6.25	31.5
Heavy Duty - Gasoline	0.95	0.36	10.9	22.7	116.9
Heavy Duty - Diesel	2.0	2.8	27.2	2.58	8.61
Suburban Roads					
Light Duty - Gasoline	0.54	0.14	4.59	6.75	38.2
Heavy Duty - Gasoline	0.95	0.36	10.3	25.0	136.3
Heavy Duty - Diesel	2.0	2.8	26.1	2.99	12.6
Urban Roads					
Light Duty - Gasoline	0.54	0.14	4.32	7.94	52.5
Heavy Duty - Gasoline	0.95	0.36	9.56	30.1	178.8
Heavy Duty - Diesel	2.0	2.8	23.8	3.68	19.2

APPENDIX D

ESTIMATION OF NO_2/NO_x ADJUSTMENT FACTOR

APPENDIX D

ESTIMATION OF NO_2/NO_x ADJUSTMENT FACTOR

Radian gathered continuous NO and NO_2 measurement data for several major U.S. cities. Table D-1 summarizes the findings. From this analysis Radian determined that 0.5 is a reasonable approximation for an urban NO_2/NO_x adjustment ratio for annual modeling purposes. This effort was not intended to be an in-depth investigation for all major U.S. cities, and no attempt was made to account for differences between or within cities. As yet, the conversion of NO (emissions) to NO_2 in the urban environment is a poorly understood phenomenon. A rough estimate for a NO_2/NO_x factor was required by this project, however, due to the lack of NO_x monitoring data to use in model calibration.

TABLE D-1

NO_2/NO_x RATIOS FOR VARIOUS CITIES

City	Years of Data	Number of Monitoring Years	Annual Average (ppb) NO	NO_2	NO_x	NO_2/NO_x
Baltimore[1]	'74-'75	4	37	55	92	0.60
Baton Rouge[3]	'74-'76	4	10	12	22	0.55
Chicago[2]	'72-'73	2	144	58	202	0.29
Ft. Worth[3]	'73-'75	6	27	24	51	0.47
Houston[3]	'74-'76	20	13	20	33	0.61
Lake Charles[3]	'74-'76	4	19	18	37	0.49
Los Angeles[4]	'74	14	64	60	124	0.48
New York[5]	'73-'74	3	47	44	91	0.48
				Average		0.50

[1] Taken from 1974 and 1975 Maryland Air Quality Report, State of Maryland Environmental Health Administration.

[2] Taken from NADB quarterly summary report.

[3] Taken by Radian Corporation's continuous monitoring stations.

[4] Taken from Air Quality and Meteorology, 1974 Annual Report, County of Los Angeles, Air Pollution Control District.

[5] Taken from New York State Air Quality Report, Continuous Monitoring System, June 1974, Semi-Annual Report.

APPENDIX E
"HOT-SPOT" ANALYSIS

APPENDIX E

"HOT-SPOT" ANALYSIS

This Appendix presents the results of the analyses at 13 selected points of interest in Chicago. The points selected were the grid locations of maximum predicted impact for individual source classes. The following pages present the results in tabular form.

Field Point No. 1

UTM Coordinates X = 435 Y = 4634

Predicted concentrations in $\mu g/m^3$

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal*	15.2	7.6	4.8
Utility - Oil	2.1	1.1	0.7
Utility - Gas	1.1	0.6	0.4
Ind. Boilers	3.3	1.7	1.1
Other Point Sources	5.6	2.8	1.8
Area Sources	122.3	61.2	38.6

Background	10
Total Predicted NO_2	57.4
Total Less Large Point Sources	50.4

Δ% = -12.2

*Class for which this field point is a "hot-spot"

Field Point No. 2

UTM Coordinates X = 439 Y = 4632

Predicted concentrations in μg/m³

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal*	14.1	7.1	4.4
Utility - Oil	1.9	1.0	0.6
Utility - Gas	0.9	0.5	0.3
Ind. Boilers	3.2	1.6	1.0
Other Point Sources	6.4	3.2	2.0
Area Sources	134.6	67.3	42.4
Background			10
Total Predicted NO_2			60.7
Total Less Large Point Sources			54.4

Δ% = -10.4

*Class for which this field point is a "hot-spot"

Field Point No. 3

UTM Coordinates X = 465 Y = 4617

Predicted concentrations in $\mu g/m^3$

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal*	11.4	5.7	3.6
Utility - Oil	0.5	.3	0.2
Utility - Gas	0.8	0.4	0.3
Ind. Boilers*	5.2	2.6	1.6
Other Point Sources	15.0	7.5	4.7
Area Sources	54.9	27.5	17.3

Background	10
Total Predicted NO_2	37.7
Total Less Large Point Sources	32.0

Δ% = -15.1

*Class for which this field point is a "hot-spot"

Field Point No. 4

UTM Coordinates X = 488 Y = 4615

Predicted concentrations in μg/m³

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	6.0	3.0	1.9
Utility - Oil*	6.5	3.3	2.0
Utility - Gas*	6.8	3.4	2.1
Ind. Boilers	1.9	1.0	0.6
Other Point Sources	6.4	3.2	2.0
Area Sources	23.4	11.7	7.4
		Background	10
		Total Predicted NO_2	26.0
		Total Less Large Point Sources	19.4

Δ% = -25.4

*Class for which this field point is a "hot-spot"

Field Point No. 5

UTM Coordinates X = 428 Y = 4637

Predicted concentrations in $\mu g/m^3$

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	6.0	3.0	1.9
Utility - Oil	0.7	0.35	0.2
Utility - Gas	0.7	0.35	0.2
Ind. Boilers*	12.8	6.4	4.0
Other Point Sources	5.8	2.9	1.8
Area Sources	120.5	60.25	38.0
Background			10
Total Predicted NO_2			56.1
Total Less Large Point Sources			49.8

Δ% = -11.2

*Class for which this-field point is a "hot-spot"

Field Point No. 6

UTM Coordinates X = 460 Y = 4611

Predicted concentrations in μg/m³

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	6.6	3.3	2.1
Utility - Oil	1.3	0.65	0.4
Utility - Gas	1.6	0.8	0.5
Ind. Boilers*	6.9	3.45	2.2
Other Point Sources	14.7	7.35	4.6
Area Sources	94.3	47.15	29.7
Background			10
Total Predicted NO_2			49.5
Total Less Large Point Sources			44.3

Δ% = -10.5

*Class for which this field point is a "hot-spot"

Field Point No. 7

UTM Coordinates X = 442.5 Y = 4640.0

Predicted concentrations in μg/m³

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	9.9	4.95	3.1
Utility - Oil	1.2	0.6	0.4
Utility - Gas	1.6	0.8	0.5
Ind. Boilers	1.8	0.9	0.6
Other Point Sources	4.4	2.2	1.4
Area Sources*	216.6	108.3	68.2
Background			10
Total Predicted NO_2			84.2
Total Less Large Point Sources			79.6

Δ% = -5.5

*Class for which this field point is a "hot-spot"

Field Point No. 8

UTM Coordinates X = 442.5 Y = 4637.5

Predicted concentrations in ug/m^3

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	10.8	5.4	3.4
Utility - Oil	1.3	0.65	0.4
Utility - Gas	1.6	0.8	0.5
Ind. Boilers	2.0	1.0	0.6
Other Point Sources	4.7	2.35	1.5
Area Sources*	229.3	114.65	72.2
Background			10
Total Predicted NO_2			88.6
Total Less Large Point Sources			83.7

Δ% = -5.6

*Class for which this-field point is a "hot-spot"

Field Point No. 9

UTM Coordinates X = 442.5 Y = 4635.0

Predicted concentrations in $\mu g/m^3$

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	11.4	5.7	3.6
Utility - Oil	1.5	0.75	0.5
Utility - Gas	1.6	0.8	0.5
Ind. Boilers	2.3	1.15	0.7
Other Point Sources	5.9	2.95	1.9
Area Sources*	213.3	106.65	67.2

Background	10
Total Predicted NO_2	84.4
Total Less Large Point Sources	79.1

Δ% = -6.3

*Class for which this field point is a "hot-spot"

Field Point No. 10

UTM Coordinates X = 442.5 Y = 4632.5

Predicted concentrations in μg/m³

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	10.2	5.1	3.2
Utility - Oil	1.2	0.6	0.4
Utility - Gas	1.6	0.8	0.5
Ind. Boilers	2.6	1.3	0.8
Other Point Sources	5.2	2.6	1.6
Area Sources*	197.1	98.55	62.1

Background	10
Total Predicted NO_2	78.6
Total Less Large Point Sources	73.7

Δ% = -6.2

*Class for which this field point is a "hot-spot"

Field Point No. 11

UTM Coordinates X = 447.5 Y = 4637.5

Predicted concentrations in μg/m^3

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	10.4	5.2	3.3
Utility - Oil	1.1	0.55	0.3
Utility - Gas	1.7	0.85	0.5
Ind. Boilers	1.7	0.85	0.5
Other Point Sources	5.7	2.85	1.8
Area Sources*	229.4	114.7	72.3

Background	10
Total Predicted NO_2	88.7
Total Less Large Point Sources	84.1

Δ% = -5.1

*Class for which this field point is a "hot-spot"

Field Point No. 12

UTM Coordinates X = 447.5 Y = 4627.5

Predicted concentrations in $\mu g/m^3$

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	10.1	5.05	3.2
Utility - Oil	1.1	0.55	0.3
Utility - Gas	1.2	0.6	0.4
Ind. Boilers	2.2	1.1	0.7
Other Point Sources	4.6	2.3	1.4
Area Sources*	225.6	112.8	71.1
Background			10
Total Predicted NO_2			87.1
Total Less Large Point Sources			82.5

$\Delta\% = -5.2$

*Class for which this field point is a "hot-spot"

Field Point No. 13

UTM Coordinates X = 447.5 Y = 4617.5

Predicted concentrations in $\mu g/m^3$

Contributing Source Class	Total NO_x	NO_2/NO_x Adjustment (Factor = 0.5)	Model Calibration Adjustment (Factor = 0.63)
Large Point Sources			
Utility - Coal	9.4	4.7	3.0
Utility - Oil	0.8	0.4	0.3
Utility - Gas	0.7	0.35	0.2
Ind. Boilers	1.9	0.95	0.6
Other Point Sources	5.6	2.8	1.8
Area Sources*	182.2	91.1	57.4
		Background	10
		Total Predicted NO_2	73.3
		Total Less Large Point Sources	69.2

$\Delta\% = -5.6$

*Class for which this field point is a "hot-spot"

APPENDIX F
TESTING OF COMMONWEALTH EDISON STEAM UNITS

APPENDIX F
TESTING OF COMMONWEALTH EDISON STEAM UNITS

Commonwealth Edison (CE) carried out a series of NO_x emissions tests on several coal-fired steam units in 1972 and 1973. The objectives of the CE NO_x test program were to obtain NO_x emission levels and all supporting data at:

1) Full or maximum load, normal operating conditons;
2) Full or maximum load, normal operating conditions with reduced oxygen.

One test was conducted by the boiler manufacturer at each condition on each boiler while firing coal. The important test conclusions were:

1) NO_x emission levels for all boilers tested, except Joliet #7, at full or maximum load under normal operating conditions were below the Federal New Source Standard for coal-fired boilers of 0.7 LBS $NO_x/10^6$ BTU-FIRED or approximately 520 PPM, dry basis adjusted to 3 percent oxygen.

2) NO_x emission levels for all boilers tested at full or maximum load under normal operating conditions with reduced oxygen were below the Federal New Source Standard for coal-fired boilers of 0.7 LBS $NO_x/10^6$ BTU-FIRED or approximately 520 PPM, dry basis adjusted to 3 percent oxygen.

All boilers tested were of the twin furnace design; therefore, separate NO_x and O_2 samples were taken on each furnace at the gas duct between the economizer outlet and the air heater inlet.

The NO_x levels from both furnaces were expected to be of the same magnitude due to duplicate design and similar operating conditions. For this reason one of the furnaces was used as a primary test furnace with 8 to 12 sampling points and the other furnace used as a secondary test furnace with 4 to 6 sampling points. On most boilers this arrangement was used, but in some cases, due to accessibility and availability of inserts, this arrangement could not be adhered to.

The NO_x emission levels were determined by the phenol-disulfonic acid method as specified in ASTM Procedure D-1603. All NO_x emission levels are reported in PPM/Volume, on a dry basis adjusted to 3 percent oxygen and as equivalent NO_x by weight in LBS/10^6 BTU-FIRED (lb/MMBtu).

Coal samples were taken on each test day and the analyses were performed in the boiler manufacturer's laboratory using ASTM Procedure D-271.

Station instrumentation was used to obtain unit operating data.

Test 2 data for operation with reduced oxygen were not used in Radian's hourly NO_x analysis of the Chicago AQCR. Radian obtained unit heat rate data for generators tested at test megawatt output values from the Commonwealth Edison dispatch center.

In addition, Collins Unit 3 has been recently tested in the same fashion as above for firing oil. The emission rate was reported as 0.22 lb/MMBTU. This value was used as a basis for scaling expected emissions from the other new Collins Units.

As may be seen from Table F-1, there are, in many cases, significant differences between test results and calculated emissions derived from AP-42 emission factors. Table F-1 presents a statistical analysis of the differences between NO_x emissions derived from the CE test program and those derived using AP-42 emission factors for coal units. This difference also exists for Collins Unit 3; AP-42 calculations would indicate that the Collins unit tested was emitting the legal limit of 0.7 lb/MMBTU, while in fact, the unit was emitting only 0.22 lb/MMBTU while under test. Because this study restricts itself to the impact of individual units on a short-term basis, test data were used where possible in the interest of accuracy.

TABLE F-1. STATISTICAL ANALYSIS OF UNIT TEST DATA VS. AP-42 FOR CE COAL UNITS*

	10 coal unit tested	9 dry bottom units tested
Mean	100.2%	95.0%
Std. Deviation	35.35%	33.2%
Range	106.0%	106.0%

*Unit tests performed 1973 by outside consultant
All on dry bottom boilers except State Line 3

APPENDIX G

COMBUSTION TURBINE AND OTHER PEAKING UNITS IN CHICAGO AQCR

APPENDIX G

COMBUSTION TURBINE AND OTHER PEAKING UNITS IN CHICAGO AQCR

CE operates two 10 MWe diesel peaking units and several diesel emergency power units at its nuclear plants; their emissions were ignored as being inconsequential.

CE also operates a number of combustion turbine (CT) peaking units which can contribute significantly to plant emissions. These units operate on the principle of a jet engine with the turbine shaft connected to a generator; in most cases, they are arranged in a tandem or multi-tandem configuration with several prime movers driving a single generator. To our knowledge, CE does not use combined-cycle CT systems. These CE units are summarized in Table G-1. An outside consultant has performed emissions testing of some of these turbines; details of this testing follow. NIPSCO also operates three 17.4 MWe CT's at Mitchell Power Plant and one 33.9 MWe CT at Bailly. Mitchell CT's No. 9A, B, and C were modeled using the characteristics of CE Crawford 31-1, 31-2, and 31-3 and Bailly 10 was modeled using the characteristics of CE Fisk 31-1. All replacement turbines were of approximately equivalent size and age as the NIPSCO units. Basic assumptions were the same as for the CE units. All combustion turbines were then, represented as follows:

1. Layout determined from site plans furnished by CE.
2. Nominal stack heights, flows, etc., determined from information furnished by CE.

TABLE G-1. SUMMARY OF CE COMBUSTION TURBINE INSTALLATIONS IN CHICAGO AQCR

Plant/Unit	Approx. ISD	Mfr.	No. of Turbines	Max MWe Output	Expected Full Load NO_x Output (lb/hr)	
					1975	1985
Calumet 31	1969	GE	4	73.7	663.2	337.6
32	1969	GE	4	73.7	663.2	337.6
33	1969	GE	4	73.7	663.2	337.6
34	1970	GE	4	76.0	692.8	347.2
Electric Junction						
31	1970	GE	4	76.0	692.8	347.2
32	1970	GE	4	76.0	692.8	347.2
33	1970	GE	4	76.0	692.8	347.2
34	1971	GE	4	76.0	692.8	347.2
Joliet 31	1969	GE	4	73.7	768.8	330.8
32	1969	GE	4	73.7	768.8	330.8
Crawford						
31	1968	GE	4	69.2	473.6	298.0
32	1968	GE	4	69.3	473.6	298.0
33	1968	GE	4	69.2	473.6	298.0
Bloom 33	1971	GE	4	76.0	713.2	338.0
34	1971	GE	4	76.0	713.2	338.0
Fisk 31	1968	P&W	2	76.0	1080.0	360.0
32	1968	P&W	2	76.0	1080.0	360.0
33	1968	P&W	2	76.0	1080.0	360.0
34	1968	P&W	2	76.0	1080.0	360.0
Waukegan						
31	1968	P&W	2	76.0	1380.0	360.0
32	1968	P&W	2	76.0	1380.0	360.0
Lombard 31	1969	P&W	2	44.3	780.0	201.6
32	1969	P&W	2	44.3	780.0	201.6
33	1969	P&W	2	44.3	780.0	201.6

GE - General Electric
P&W - Pratt and Whitney

3. Test data used where possible; otherwise, NO_x emissions scaled based on tests of other units or same unit (when insufficient data exists). Only No. 2 fuel oil was considered.

4. Test data shows units out of compliance with Illinois regulations; 1985 values are those with units in compliance.

5. Maximum power output is 100 percent of rated; block loading not required.

Because of the high exit temperatures and volumetric flow rates, CT plumes interact with steam unit plumes in most cases. This was substatiated through modeling.

An outside consultant has performed emissions testing on some of Commonwealth Edison's combustion turbine (CT) peaking units. The turbines were selected as representative of the variety in use in the system. Testing was conducted from January through May of 1974.

Emissions of gaseous pollutants were measured in a self-contained instrumentation van using continuous electronic instrumentation. Nitrogen oxides (NO and NO_x) and carbon monoxide were measured in this manner. Excess oxygen, which is used in the data analysis, was also measured instrumentally. Continuous gaseous emission measurements were made over the turbine operating load range and for all available fuels.

Nitrogen oxides were also measured by the wet chemical PDS method at selected points for comparison with instrumental results.

Total aldehydes were measured by the MBTH method using a wet chemical absorption sampling train.

Particulate emissions were measured using primarily the Federal EPA sampling train. This technique uses an out-of-stack collection filter in a heated oven to avoid water condensation. Particulate testing was also performed using the ASME in-stack filter method.

Sulfur oxide emissions levels were calculated from individual fuel analyses taken at each site.

The emission tests were conducted to assess compliance with the Illinois State Pollution Control Board Air Pollution Regulations for stationary sources. These regulations are summarized below:

NO_x — 0.3 lb/MMBTU burning either oil or gas (existing)
SO_x — 0.3 lb/MMBTU burning distillate fuel (effective 5/30/75)
CO — 200 ppm at 50% excess air (existing)
Particulates — 0.1 lb/MMBTU measured by ASME Method (effective 5/30/75)
Aldehydes — not regulated

A tabular summary of the program results are presented in Table G-2. Nitrogen oxides, carbon monoxide, sulfur oxides, aldehydes, and particulates are summarized at base load for each of the units and fuels tested.

NO_x emissions at the normal operating base load exceeded the regulation for all turbines tested. The one

TABLE G-2. SUMMARY OF EMISSIONS FROM CE CT's TESTED
(FURNISHED BY CE)

								Emissions at Base Load					
								ppm	Average lb/MBtu				
												Particulates	
Station	Unit	Fuel	Additive	Mfg.	Model	Can Type	Atomization	CO @ 50% Excess Air	NOx as NO_2	SOx as SO_2 (Calc.)	Aldehydes as Formaldehyde	EPA Standard	ASME
Electric Junction	34-4	#2 Oil	None	GE	5000 M	Smokeless	Pressure	0	0.554	0.062			
Electric Junction	33-4	#2 Oil	None	GE	5000 LA	Smokeless	Air	0	0.543	0.062	7.2×10^{-4}	0.0182	0.0036
Crawford	32-4	#2 Oil	CI2	GE	5000 L	Original	Pressure	54	0.460	0.346	4.9×10^{-4}	0.0340	-
		Gas	-					0	0.396	-	-	-	-
Lombard	32-1	#1 Oil	None	PW	GG4-FT4A-9	Smokeless	Pressure	128	0.836	0.291	30.3×10^{-4}	0.0167	-
		Gas						338	0.423	-	-	-	-
Fisk	31-1	#1 Oil	None	PW	GG4A-4DF	Smokeless	Pressure	145	0.686	0.065	-	0.0152	-
		#2 Oil	None					101	0.667	0.122	-	0.0250	-
		#2 Oil	DGT-2					115	0.734	0.192	-	0.0206	-
Calumet	32-1	#2 Oil	CI2	GE	5000 LA	Original	Pressure	107	0.527	0.164	-	-	-
Joliet	32-4	#2 Oil	CI2	GE	5000 LA	Original	Pressure	78	0.581	0.196	-	-	-
Bloom	33-1	#2 Oil	None	GE	5000 M	Smokeless	Pressure	27	0.519	0.247	21.8×10^{-4}	0.0204	0.0102
		Gas	-					29	0.266	-	-	-	-
Sabrooke	34-2	#2 Oil	None	GE	5000 LA/M	Smokeless	Air	26	0.527	0.331	-	-	-
Waukegan	31-2	#1 Oil	None	PW	GG4-4LF	Smokeless	Pressure	105	0.593	0.040	57.8×10^{-4}	0.0155	0.0114

exception was a GE 5000 M at Bloom Station using a smokeless can while burning natural gas. On oil this turbine did exceed the regulation. On the average about a 50 percent reduction is required to meet the regulation. The Pratt-Whitney turbine NO_x emissions are generally higher than the various GE 5000 models. NO_x emissions in lb/MMBTU decreased as load decreased. Water injection is the only technique that will guarantee compliance. Low NO_x dry combustor cans are being developed.

Most NO_x test data were taken using electronic instrumentation. PDS flask data were taken at selected points to establish correspondence between the instrumental and wet chemical (PDS) measurement methods. Agreement between the two was acceptable according to CE's consultant.

Gas turbine emissions were measured for three fuels: No. 1 fuel (turbine) oil, No. 2 fuel oil, and natural gas. The No. 2 fuel oil was tested with and without additives. Two different types of additives were used: CI2 at 40, 50 and 75 ppm concentrations, and DGT2 at 168, 251 and 335 ppm concentrations.

Samples of the oil were obtained during the tests at each turbine test site and submitted for laboratory analysis. A summary of the oil analysis results is shown in Table G-3. along with typical values reported for these two fuels. In using these oil fuel analyses to reduce measured particulate weights and gaseous emissions to lb/MMBTU, an average analysis was used for each of the types of oils. For gas fuel, the test data were reduced using a typical gas fuel analysis, as shown in the Table.

The fuel oil was analyzed by three companies; this

TABLE G-3. FUEL PROPERTIES AND COMPOSITION FOR TESTS (FURNISHED BY CE)

Station	Turbine No.	Fuel Type	Additive	Carbon % b.w.	Hydrogen % b.w.	Sulfur % b.w.	Nitrogen % b.w.	Ash % b.w.	Oxygen % b.w. by diff.	Water ppm	API @ 60°F	HHV Btu/lb	C/H Ratio	Calc. SO_2 lb/MBtu	Analyzing Lab
Electric Junction	34-4	#2 Oil	None	86.29	12.82	0.06	0.07	0.01	0.75	-	34.3	19,337	6.731	0.062	CTE
	33-4														
Crawford	32-4	#2 Oil	CI2 75 ppm	87.13	12.36	0.34	0.028	0.011	0.13	26.9	35.6	19,650	7.049	0.346	PCL
		#2 Oil	CI2 75 ppm	86.95	12.67	0.21	0.022	0.0	0.15	63.0	34.7	19,406	6.863	0.214	PCL
Lombard	32-1	#1 Oil	None	85.60	13.77	0.29	0.02	0.006	0.32	28.1	42.4	19,900	6.226	0.291	PCL
Fisk	31-1	#2 Oil	None	86.52	13.25	0.12	0.023	0.012	0.08	70.1	37.4	19,599	6.530	0.122	PCL
		#2 Oil	DCT2 335 ppm	86.54	13.06	0.19	0.010	0.011	0.19	138.5	35.4	19,524	6.626	0.195	PCL
		#1 Oil	None	85.79	14.12	0.076	0.012	0.004	0	78	50.2	20,365	6.076	0.075	PCL
		#1 Oil	None	85.53	14.40	0.056	0.011	0.009	0	79	51.4	20,474	5.940	0.055	PCL
Calumet	32-1	#2 Oil	CI2 40 ppm	86.71	12.80	0.16	0.017	<0.001	0.31	87	35.1	19,540	6.774	0.164	KVB
Joliet	32-4	#2 Oil	CI2 50 ppm	86.62	12.66	0.19	0.022	<0.001	0.51	198	34.7	19,430	6.842	0.196	KVB
Bloom	33-1	#2 Oil	None	87.05	12.58	0.24	0.023	<0.001	0.11	96.8	34.6	19,420	6.920	0.247	KVB
Sabrooke	34-2	#2 Oil	None	86.81	12.65	0.32	0.014	<0.001	0.21	-	33.9	19,340	6.862	0.331	KVB
Waukegan	31-2	#1 Oil	None	86.08	13.98	0.044	0.006	<0.001	0.11	-	46.4	19,850	6.157	0.044	KVB
		#1 Oil	None	85.95	13.90	0.037	0.006	<0.001	0.11	-	45.7	19,850	6.187	0.037	KVB
	TYPICAL #2 OIL			87.2	12.5	0.3	-	Nil	Nil	Nil	32.0	19,430	6.976	0.309	
	TYPICAL #1 OIL			86.1	13.8	0.1	0.02	Nil	Nil	Nil	42.0	19,810	6.239	0.101	
	TYPICAL NATURAL GAS			73.9	23.0	Nil	2.5	Nil	0.6	Nil	-	23,440	3.213	Nil	

analysis was made according to the following specifications and methods:

Water - Karl-Fischer, ASTM D-1744
Carbon - Pregl Method
Hydrogen - Pregl Method
Sulfur - ASTM D129
Nitrogen - ASTM D3228 (Kjeldahl nitrogen)
Ash - ASTM D482
Oxygen - By difference
Heating Value - ASTM D240-64
API Gravity - ASTM D287-67
Viscosity (@ 100°F) - ASTM D445

The sulfur content and heating value of the fuel were used to calculate sulfur oxide emissions as SO_2, in lb/MMBTU.

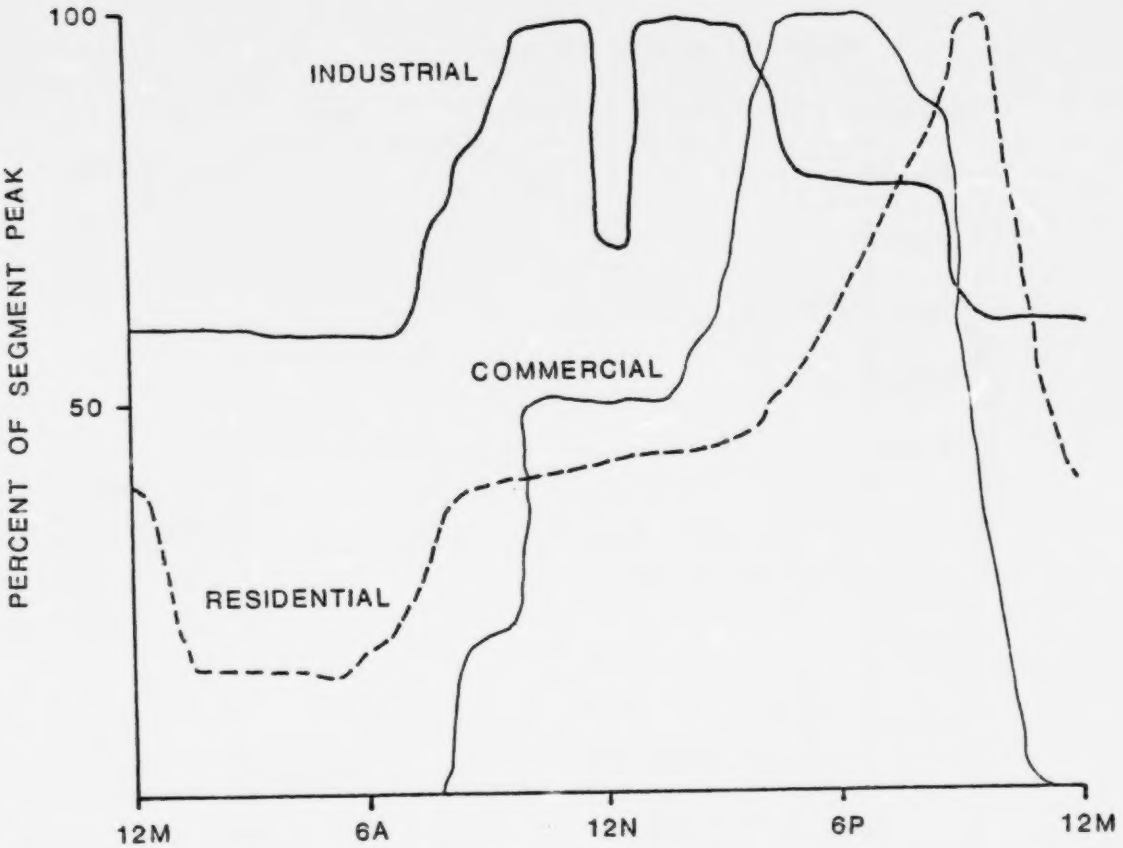
The heating value determined by ASTM D240-64 is a higher heating value; i.e., the water vapor formed is in liquid form following combustion in the calorimeter. This higher heating value is in general use throughout the boiler industry. The latent heat of moisture in the fuel must then be considered as a stack loss in efficiency calculations. All data were reduced in terms of this higher heating value (HHV).

APPENDIX H
POWER PLANT EMISSIONS CHARACTERIZATION

APPENDIX H
POWER PLANT EMISSIONS CHARACTERIZATION

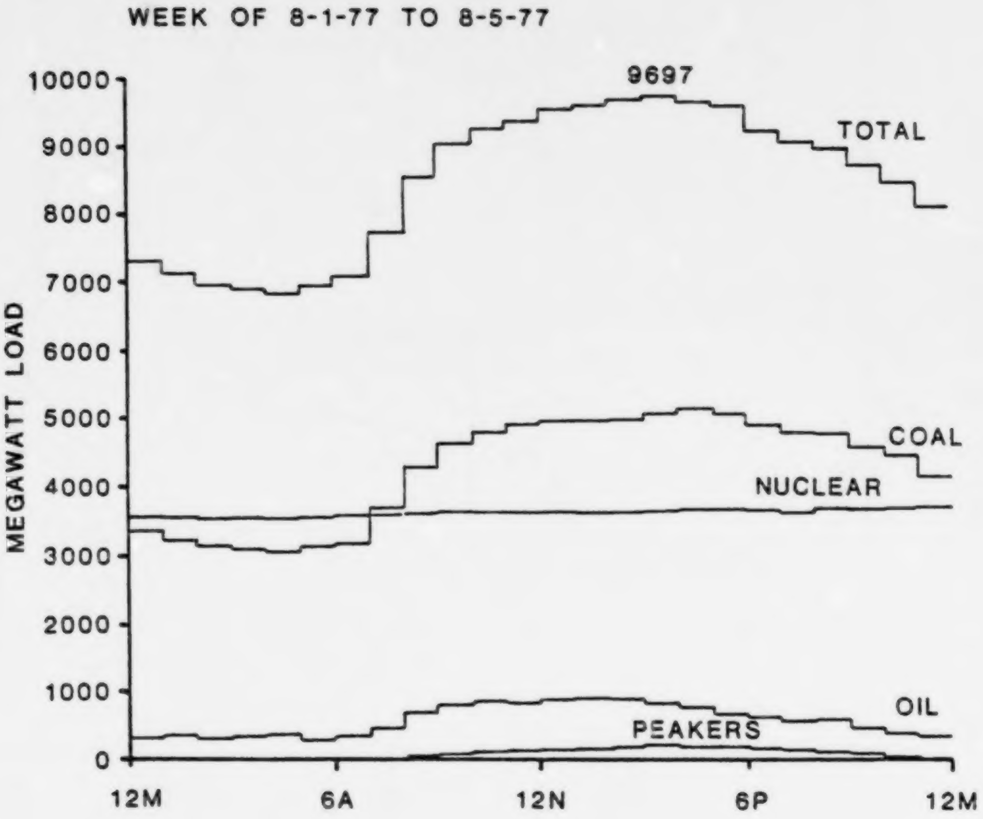
Utility-owned steam-electric power generating plants in the Chicago AQCR are operated by the Commonwealth Edison Company (CE), Northern Indiana Public Service Company (NIPSCO), and the Village of Winnetka (Winnetka Muni). All of these steam units are larger than 25 MWe capacity. Non-utility power plants are owned by Bethlehem Steel (Burns Harbor Works, Porter County, Indiana), Texaco (Lockport Refinery, Will County, Illinois), Corn Products, and O'Hare International Airport (standby plant). This standby power plant at O'Hare International Airport and the coal-fired cyclone unit operated by Corn Products (20 MWe) were omitted because the former is insignificant and there are no data available on the latter. The omission of these two units does not significantly affect the results of this study.

All utility power plant emissions were evaluated for 1975 and expected emissions were evaluated for 1985. Typical electrical demand as a function of time of day for various consumer types are shown in Figure H-1. These demands produce curves, such as the Commonwealth Edison typical summer demand curve shown in Figure H-2. The shape of these curves and, hence, hourly demand on system generation, are functions of sociological conditions (such as income), weather, sports events, television programs, diversity of load makeup (percent residential, industrial, and commercial customers), day of the week, etc., and can vary significantly from day to day and season to season. Load (or demand), in turn, affects the utility's choice of units online and their individual power settings. Emissions, then, are a direct function of system and unit loading. Unit loadings



TYPICAL ELECTRICAL DEMAND BY SEGMENT

Figure H-1



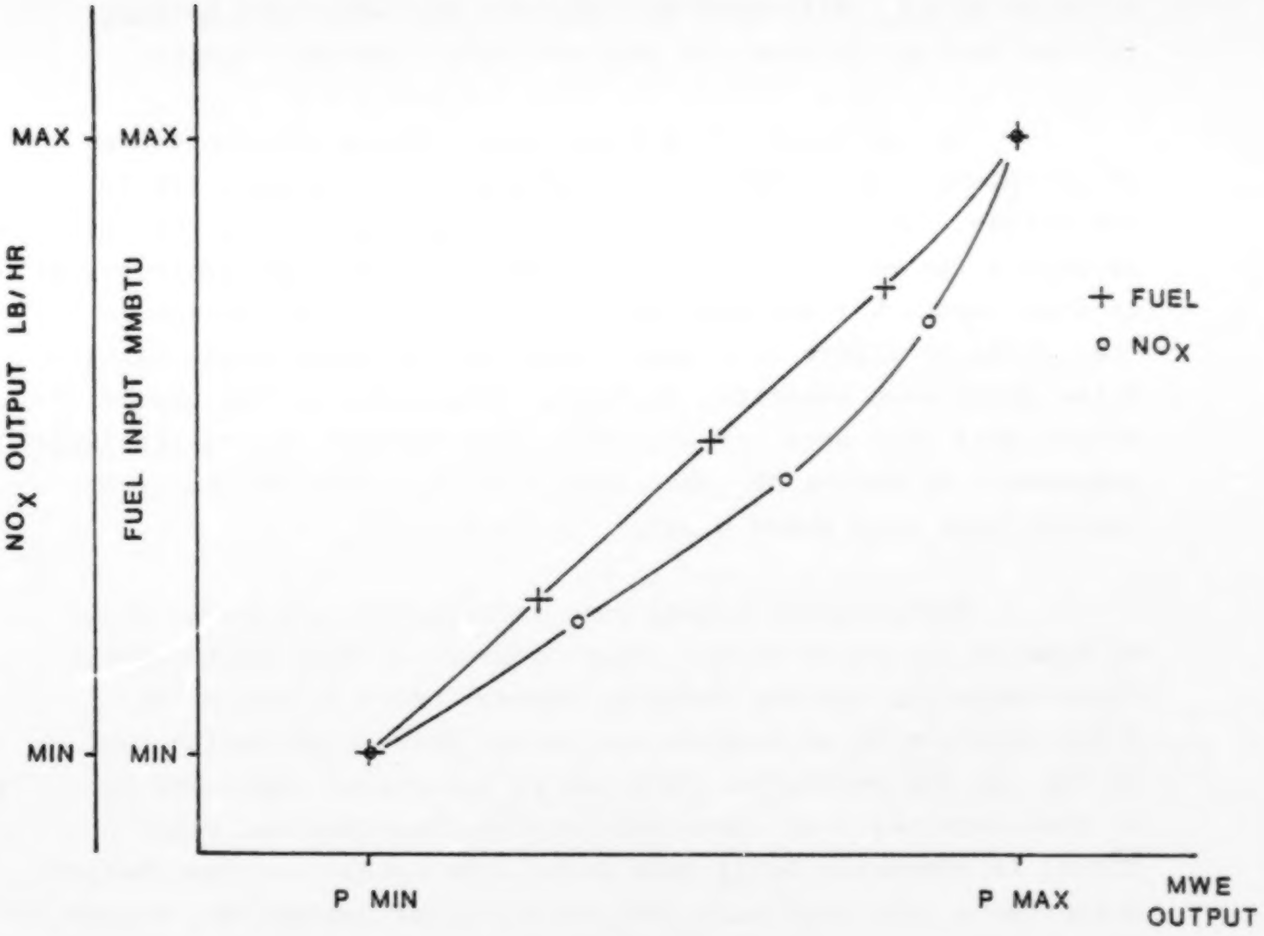
COMMONWEALTH EDISON AVERAGE SYSTEM LOAD

Figure H-2

are generally influenced by the types and amounts of generation available, reserve requirements, and the incremental heat rates (or cost of the next megawatt to be added or removed) of the individual units. All these factors must be taken into account in some fashion in order to realistically evaluate impacts.

NO_x emissions from steam power plants are functions of residence time, temperature, turbulence, and excess air in the boiler. In coal-fired plants, nitrogen content of the fuel is also a factor. In general, NO_x emissions are not proportional to fuel input, but instead follow a characteristic similar to that shown in Figure H-3; also, there can be significant variation among even identical boilers. Consequently, the use of actual unit test data, if available, can provide a more realistic assessment of boiler NO_x emissions than any other method; test results were used where possible in this study.

Commonwealth Edison has performed NO_x emissions tests on some of its steam units. They covered all coal units except those employing cyclone furnaces (exempt under Illinois law). Tests were run by an outside consultant using high sulfur coal. CE has, in the meanwhile, switched to low sulfur coal, and it is thus expected that these data may be conservative, since firing is presently being done using less excess air than before. Approximate data have also been obtained for nominal NO_x output from cyclone furnaces. These data from cyclone units are based on utility heat rate and fuel analysis data, and AP-42 emission factors. In addition, CE operates one oil-fired plant (Ridgeland) and is presently adding another (Collins). Collins Unit 3 has been tested and the results of the test have been incorporated in this study. In computing expected NO_x stack output for CE units, the following points were incorporated or noted:



TYPICAL FUEL AND NO_X CHARACTERISTICS FOR STEAM UNIT
(Value Points Omitted)

Figure H-3

1. FPC Form 67 and AP-42 emission factors used for the following units:

Crawford 6/Gas	(104 MW-Retired Aug. 1976)
Calumet 7/Gas	(107 Mw-Retired Sept. 1975)
Ridgeland 1/Resid. Oil	(173 Mw)
Ridgeland 2/Resid. Oil	(173 Mw)
Ridgeland 3/Resid. Oil	(173 Mw)
Ridgeland 4/Resid. Oil	(173 Mw)

   It is assumed that the Ridgeland units will continue to burn oil for two reasons:[1]
   a) Ambient pollution levels tend to be greater than maximum allowable for coal.
   b) Proximity of stacks to end of northwest-southeast runways at Midway Airport.

2. For untested units in plants where testing was done, an average higher heating value (HHV) based on coal HHV from tests was used.

3. Collins 3 test data were used as expected values for remainder of Collins units.

4. It should be noted that the following cyclone units in the Chicago AQCR are exempted from NO_x standards by state law:

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[1] Radian Corporation, Assessment of the Air Quality Impact of Converting Ridgeland Generating Station (Commonwealth Edison) to Coal, Revised Final Report, Federal Energy Administration, Office of Fuel Utilization, 31 July 1975.

Joliet 5,6	(85 MWe, 340 MWe)
Will County 1,2	(114 MWe, 167 MWe)
State Line 4	(318 MWe)
Fisk 18	(129 MWe)

5. Powerton (2-850 MWe each) and Kincaid (2-606 MWe each) are large cyclone base load units not in the Chicago AQCR.

6. Unit stack parameters were linearly extrapolated or interpolated from FPC Form 67 data when unit loadings were not 100% of Form 67 value.

In addition, tests were performed on many CE combustion turbine (CT) peaking units; data concerning these tests are in Appendix C.

For stations existing in 1975, stack data were determined from FPC Form 67 (and CE site plans, when necessary). For the Collins Station, which is only partially complete at the present time, the following procedure was followed:

1. Stack locations were determined from site plan dated 2/1/76 (furnished by utility) and signed by H. D. Clemens, P.E. (Illinois).

2. Stack gas exit temperature was the high value national average for SCC code 1-01-004-01.

3. Volumetric flow rate was scaled from data for Powerton stack.

Other steam power plants in the Chicago AQCR are the NIPSCO D. H. Mitchell and Bailly Plants, and the Winnetka Municipal Power Plant. Emissions data for these plants were obtained from AP-42, FPC Form 67, and utility-supplied data. No emissions test data were used for the steam boilers associated with these plants. As previously mentioned, the Corn Products and O'Hare Airport units were omitted. The Bethlehem Steel and Texaco Plant data were obtained from NEDS and an analysis determined that these units probably operate at maximum power output 100 percent of the time.

Because the CE generating units use once-through cooling, water temperature plays a large part in determining the maximum power output levels and, hence, the maximum feasible emissions. Data from CE indicates that during a summer peak period when the emissions problem may be the worst, the units are capable of producing only 85-90 percent of rated power; for a winter peak, the level is 95-96 percent of rated. For this study, values of 90 percent in the summer and 95 percent in the winter were used. These values were also applied to the NIPSCO and Winnetka Plants.

Diurnal variations in power plant emissions were simulated by calculating unit loadings based on heat rate and utility use (base load, peaking, etc.). These data were obtained from CE, NIPSCO, and the Village of Winnetka. This process yielded results which were similar to those obtained by each utility's economic dispatch process. In addition, load forecasts to 1986 were made for the CE and NIPSCO electric system, and data from these were also used to determine loadings. These forecasts are shown in Tables H-1 and H-2. Unit retirement and initial startup data were obtained from the utilities and used in this forecast.

TABLE H-1. CE LOAD FORECAST

Year/Season	Time	Expected Demand	Comments
1975 Summer	Mid PM	12,300 MWe	
	Mid AM	8,100 MWe	From utility data
	Mid AM	6,800 MWe	
1975 Winter	Mid PM	9,000 MWe	Elect. World Dir. of Utilities
	Mid AM	6,500 MWe	(8100 x 9/12.3 + 500)
	Mid AM	5,900 MWe	(6500 x 9/12.3 + 1000)
1985 Summer	Mid PM	21,700 MWe	Load forecast
	Mid AM	18,000 MWe	ratio 1975 summer rounded
	Early AM	16,000 MWe	based on nuclear and base steam
1985 Winter	Mid PM	16,000 MWe	Load forecast
	Mid AM	14,000 MWe	ratio 1975 winter rounded
	Early AM	13,000 MWe	based on maximum nuclear capability

TABLE H-2. NIPSCO LOAD FORECAST

Year/Season	Time	Expected Demand
1975 Summer	Mid PM	1800 MWe
	Mid AM	1970 MWe
	Early AM	1550 MWe
1975 Winter	Mid PM	1675 MWe
	Mid AM	1600 MWe
	Early AM	1500 MWe
1985 Summer	Mid PM	2925 MWe
	Mid AM	2850 MWe
	Early AM	2700 MWe
1985 Winter	Mid PM	2675 MWe
	Mid AM	2600 MWe
	Early AM	2500 MWe

Typical generating unit loadings for 1975 and 1985 are shown in Tables H-3 and H-4, and equivalent NO_x output for 1975, in Table H-5. These values can be compared to worst-case values of 90 percent load in all units except CT's in the summer and 95 percent load in all units except CT's in the winter (all CT's at 100 percent). In general, the closer the typical loads are to the worst-case, the more likely that the worst-case can be attained on a routine basis.

In addition, Table H-6 details a comparison made between cyclone and non-cyclone boiler emissions for 1975. In the typical and extreme cases, it can be seen that 22-26 percent of the shaft megawatts generated are responsible for 44-50 percent of the NO_x emitted. This would indicate that controls on cyclone units alone might have a very significant effect on NO_x emissions. This is important because one effect of the proposed NSPS for SO_2 might be a renewed interest in the burning of medium sulfur Midwestern coals which can be burned more efficiently in cyclone furnaces.

TABLE F-3 1975 ESTIMATED UNIT LOADINGS

				Summer			Winter		
Plant/Unit System		Use	Max. MWe	% Max Mid PM 12,300 MWe	% Max Mid AM 8,100 MWe	% Max Early AM 5,300 MWe	% Max Mid PM 9,000 MWe	% Max Mid AM 6,500 MWe	% Max Early PM 5,900 MWe
Joliet	5	P	83	75	15	15	0	0	0
	6	IB	340	90	50	15	50	15	15
	7	B	581	90	90	90	95	95	75
	8	B	575	90	90	90	95	95	95
Waukegan	5	P	122	75	15	15	0	0	0
	6	P	88	75	15	15	0	0	0
	7	IB	305	90	50	15	75	15	15
	8	IB	305	90	50	25	75	15	15
Will County	1	IP	144	90	25	15	0	0	0
	2	IP	164	90	25	15	0	0	0
	3	IP	217	90	25	15	0	0	0
	4	IB	435	90	50	25	75	15	15
State Line	1	P	171	75	15	15	0	0	0
	2	P	140	75	15	15	0	0	0
	3	IP	238	90	25	15	0	0	0
	4	IB	318	90	50	25	75	15	15
Crawford	6	IP	104	90	25	15	0	0	0
	7	IP	205	90	25	15	0	0	0
	8	IB	360	90	75	25	75	15	15
Fisk	18	IP	129	75	15	15	0	0	0
	19	IB	343	90	25	25	75	15	15
Ridgeland	1	P	173	75	15	15	0	0	0
	2	P	173	75	15	15	0	0	0
	3	IP	173	90	25	15	0	0	0
	4	IP	173	90	25	25	15	15	15
Calumet	7	IP	127	90	25	15	0	0	0
Nuclear		B	3600	100	83	83	100	83	83
Peakers	CT	P	1697	50%@100%	0	0	10%@100%	0	0
Mitchell	4	I	138	90	90	90	90	90	90
	5	I	138	90	90	90	90	90	90
	6	I	138	90	90	90	90	90	90
	11	IP	115	90	90	90	90	75	75
Bailly	7	IB	194	90	90	90	95	95	95
	8	B	422	90	90	90	95	95	95
Peakers	CT	P	36.1	100%	100%	0	100%	0	0
	1	P	25.5	75	25	15	50	25	15
	5	S	25.5	15	15	15	15	15	15

P - Peaking
I - Intermediate
B - Base
S - Standby

TABLE H-4. 1985 ESTIMATED UNIT LOADINGS

Plant/Unit System		Use	Max. MWe	Summer % Max Mid PM 21,700 MWe	 % Max Mid AM 18,000 MWe	 % Max Early AM 16,000 MWe	Winter % Max Mid PM 16,000 MWe	 % Max Mid AM 14,000 MWe	 % Max Early PM 13,000 MWe
Joliet	5	P	85	50	15	15	0	0	0
	6	IB	340	90	75	50	50	25	15
	7	B	581	90	90	90	95	95	75
	8	B	575	90	90	90	95	95	75
Waukegan	5	P	122	50	15	15	0	0	0
	6	P	88	50	15	15	0	0	0
	7	IB	305	90	75	50	50	25	15
	8	IB	305	90	75	50	50	25	15
Will County	1	IP	144	75	25	15	0	0	0
	2	IP	167	75	25	15	0	0	0
	3	IP	217	75	25	15	0	0	0
	4	IB	455	90	75	50	50	25	15
State Line	1	P	171	50	15	15	0	0	0
	2	P	140	50	15	15	0	0	0
	3	IP	237	75	25	15	0	0	0
	4	IB	318	90	75	50	50	25	15
Crawford	7	IP	205	75	25	15	0	0	0
	8	IB	360	90	75	50	50	25	25
Fisk	18	P	129	50	15	15	0	0	0
	19	IB	343	90	75	50	50	25	15
Ridgeland	1	P	173	50	15	0	0	0	0
	2	P	173	50	15	0	0	0	0
	3	IP	173	75	25	15	0	0	0
	4	IP	173	75	25	15	15	15	15
Collins	1	IB	520	75	50	50	50	25	15
	2	IB	520	90	75	50	50	25	15
	3	IB	503	90	75	50	50	15	15
	4	IB	503	90	75	50	50	15	15
	5	IB	503	90	75	50	50	15	15
Nuclear		B	11,000	100	100	90	100	100	90
Peakers	CT	P	1697	80%@100%	0	0	10%@100%	0	0
Mitchell	4	I	138	90	90	90	95	95	95
	5	I	138	90	90	90	95	95	95
	6	I	138	90	90	90	95	95	95
	11	IP	115	90	90	90	95	95	95
Bailly	7	IB	194	90	90	90	95	95	95
	8	B	422	90	90	90	95	95	95
Peakers	CT	P	86.1	100%	100%	0	100%	100%	0
Winnetka	1	P	25.5	75	25	15	50	25	15
	3	S	25.5	15	15	15	15	15	15

P - Peaking
I - Intermediate
B - Base
S - Standby

TABLE H-5. 1975 ESTIMATED NO_x FROM POWER PLANTS (Lb/Hr)

PLANT/UNIT		SUMMER			WINTER		
		MId PM	MID AM	EARLY AM	MID PM	MID AM	EARLY AM
UTILITY							
Joliet	5*	1745	420	420	0	0	0
	6*	7447	4215	1490	4215	1490	1490
	7	6525	6525	6525	6885	6885	5435
	8	6085	6085	6085	6425	6425	5075
Waukegan	5	1550	370	370	0	0	0
	6	1650	395	395	0	0	0
	7	3240	1835	650	2700	650	650
	8	3050	1730	950	2545	610	610
Will County	1*	3620	1125	725	0	0	0
	2*	4245	1320	850	0	0	0
	3	2050	640	410	0	0	0
	4	3700	2095	1150	3080	740	740
State Line	1	1695	405	405	0	0	0
	2	1620	385	385	0	0	0
	3	1760	545	350	0	0	0
	4*	6630	3760	2065	5525	1325	1325
Crawford	6	805	250	160	0	0	0
	7	1055	330	210	0	0	0
	8	2330	1945	725	1945	465	465
Fisk	18*	3100	745	745	0	0	0
	19	2845	885	885	2370	570	570
Ridgeland	1	990	235	235	0	0	0
	2	990	235	235	0	0	0
	3	1185	370	235	0	0	0
	4	1185	370	370	235	235	235
Calumet	7	390	120	80	0	0	0
Mitchell	4	905	905	905	905	905	905
	5	905	905	905	905	905	905
	6	905	905	905	905	905	905
	11	795	795	795	795	660	660
Bailly	7*	4455	4455	4455	4705	4705	4705
	8*	9010	9010	9010	9510	9510	9510
Winnetka	1	135	50	35	95	50	35
	5	35	35	35	35	35	35
C. E. Peakers		10,000	0	0	2000	0	0
NIPSCO Peakers		895	895	0	895	895	0
Total Emissions		99,520	55,290	44,150	56,675	37,965	34,255
NON-UTILITY							
Bethlehem Steel	1	2027	2027	2027	2027	2027	2027
	2	2027	2027	2027	2027	2027	2027
	3	2027	2027	2027	2027	2027	2027
	4	2027	2027	2027	2027	2027	2027
	5	2027	2027	2027	2027	2027	2027
Texaco Lockport	1	86	86	86	86	86	86
Total Emissions		10,221	10,221	10,221	10,221	10,221	10,221

*Cyclone Furnace

TABLE H-6. COMPARISON OF CYCLONE AND NON-CYCLONE FURNACES 1975 ESTIMATED ESTIMATED NO_x EMISSIONS

	Summer			Winter		
	Mid PM	Mid AM	Early AM	Mid PM	Mid AM	Early AM
Total Units Available	34	34	34	18	18	18
No. Cyclones Available	8 (23.5%)*	8 (23.5%)	8 (23.5%)	4 (22.2%)	4 (22.2%)	4 (22.2%)
No. Cyclones On-Line	8 (23.5%)	6 (17.6%)	3 (8.8%)	4 (22.2%)	2 (11.1%)	2 (11.1%)
No. Cyclones Spinning Reserve	0 (0.0%)	2 (5.9%)	5 (14.7%)	0 (0.0%)	2 (11.1%)	2 (11.1%)
Total Units On-Line	33 (97.0%)	25 (73.5%)	14 (41.2%)	16 (88.9%)	9 (50.0%)	8 (44.4%)
Total Units Spinning Reserve	1 (3.0%)	9 (26.5%)	20 (58.8%)	2 (11.1%)	9 (50.0%)	10 (55.6%)
Cyclone Capacity On-Line (MWe)	1799.0 (23.9%)	1585 (21.1%)	934 (12.4%)	1274 (25.7%)	616 (12.4%)	616 (12.4%)
Cyclone Capacity Spinning Reserve (MWe)	0.0 (0.0%)	214 (2.8%)	865 (11.5%)	0.0 (0.0%)	658 (13.3%)	658 (13.3%)
Total Capacity On-Line (MWe)	7499.5 (99.7%)	6418.5 (85.3%)	4566 (60.7%)	4752.5 (96.0%)	2326.5 (47.0%)	2301 (46.5%)
Total Capacity Spinning Reserve (MWe)	25.5 (0.3%)	1106.5 (14.7%)	2959 (39.3%)	198.5 (4.0%)	2624.5 (53.0%)	2650 (53.5%)
Total Shaft (MWe)	6463.2	3842.5	3029.2	3936.5	2542.3	2308.55
Cyclone Shaft MWe	1587.0	993.25	763.65	993.7	683.9	683.9
Cyclone % of Total Shaft MWe	24.6%	25.8%	25.2%	25.2%	26.9%	29.6%
Total Emissions from Steam Boilers	88,625	54,395	44,150	53,780	37,070	34,255
Total Emissions from Cyclones	40,245	25,050	19,760	23,955	17,030	17,030
Percentage of Total Emissions from Cyclones	45.4%	46.1%	44.8%	44.5%	45.9%	49.7%
Cyclone % of Total Shaft MWe	24.6%	25.8%	25.2%	25.2%	26.9%	29.6%
Cyclone % of Available Capacity	23.9%	23.9%	23.9%	25.7%	25.7%	25.7%
Cyclone % of Available Units	23.5%	23.5%	23.5%	22.2%	22.2%	22.2%

*Percentage of Total.

APPENDIX I
NIPSCO AND NIGC GAS SENDOUT DATA

APPENDIX I

NIPSCO AND NIGC GAS SENDOUT DATA

The following data concerning gas sendout were obtained from Mr. T. R. Howorth, NIPSCO , and Mr. Norbert Oliver, NIGC.

Monthly Gas Sendout
Year 1975
Lake and Porter Counties, Indiana

The tabulation that follows shows the sales (sendout) of natural gas in Lake and Porter Counties, Indiana, by months for the year 1975, based on the operating records of Northern Indiana Public Service Company. The operating records do not segregate sales by counties, but instead show sales by operating districts of the company. In order to derive sales by counties, assumptions were made about the geographical distribution of gas loads in each of the districts under consideration and gas sendout was then assigned to the appropriate counties.

The distribution of sendout and the assumptions used to distribute sendout were:

1. All of Hammond district load is in Lake County.
2. All of Gary district load is in Lake County.
3. Half of Hobart district residential and commercial load is in each of the two counties.
4. All of the Hobart district industrial and other load is in Porter County, none in Lake County.
5. In Crown Point district, nine-tenths of the residential and commercial load and all of the industrial and other load is in Lake County.
6. In Valparaiso district, half of the residential, nine-tenths of the commercial and all of the industrial and other load is in Porter County.
7. In Michigan City district, half of the residential, two-tenths of the commercial, nine-tenths of the industrial and all of the other load is in Porter County.

The tabulation is a summation of the loads in the several districts distributed as indicated above.

There is a gas load variation during each day that cannot be quantified but which follows a characteristic pattern both winter and summer. The amplitude of the variation is not as great in the summer as in the winter, however.

In the morning between 0500 and 0900 hours the load will usually rise to a peak about 50% higher than the daily average hourly load. There is another peak between 1600 and 2000 hours about 25% higher than the daily average hourly load. The pattern is the same both winter and summer, but because of space heating, the winter daily peaks are more pronounced, perhaps by 10 to 20%.

There is also a difference between daily and weekend loads. A typical Saturday or Sunday load would be 10% or so lower than a weekday load.

Gas Sales (MCF @ 1000 Btu)

	Lake County	Porter County
January 1975		
Residential	3,003,920	668,700
Commercial	1,477,260	245,110
Industrial	9,116,400	1,313,600
Other	12,700	8,000
February 1975		
Residential	3,292,190	651,650
Commercial	1,103,480	215,660
Industrial	8,503,900	1,195,740
Other	36,300	2,300
March 1975		
Residential	3,037,030	602,000
Commercial	1,015,830	200,470
Industrial	8,143,100	1,035,130
Other	23,900	2,900
April 1975		
Residential	2,696,850	539,400
Commercial	1,297,790	612,770
Industrial	8,363,700	1,083,160
Other	49,000	5,200
May 1975		
Residential	1,555,700	305,900
Commercial	465,470	92,230
Industrial	7,348,500	1,151,220
Other	28,100	2,200
June 1975		
Residential	790,510	150,050
Commercial	255,200	39,350
Industrial	7,925,400	1,564,640
Other	16,300	1,500
July 1975		
Residential	556,460	110,450
Commercial	196,110	27,700
Industrial	7,444,200	1,403,500
Other	11,500	1,000

	Lake County	Porter County
August 1975		
Residential	518,510	96,100
Commercial	179,600	26,960
Industrial	8,213,100	1,488,010
Other	11,500	900
September 1975		
Residential	1,017,880	121,650
Commercial	205,740	35,530
Industrial	8,920,500	1,741,060
Other	12,300	1,300
October 1975		
Residential	972,420	200,900
Commercial	286,460	59,640
Industrial	8,940,900	1,570,850
Other	18,600	1,800
November 1975		
Residential	1,330,370	278,350
Commercial	414,350	88,490
Industrial	9,767,700	1,846,560
Other	24,400	1,000
December 1975		
Residential	2,644,310	546,050
Commercial	772,730	171,890
Industrial	10,489,200	1,916,190
Other	23,700	1,700

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NORTHERN ILLINOIS GAS COMPANY

Estimated Large-Volume Commercial and Industrial Gas Sendout

Chicago Air Quality Control Region

Mcf @ 1,000 Btu and 14.65 Psia

1975	Sendout
Jan.	7,671,000
Feb.	7,645,000
Mar.	7,352,000
Apr.	6,903,000
May	6,955,000
June	6,637,000
July	6,992,000
Aug.	6,825,000
Sept.	6,995,000
Oct.	6,802,000
Nov.	7,275,000
Dec.	7,162,000
Total	85,214,000

10-17-77

NORTHERN ILLINOIS GAS COMPANY

Estimated Total Daily Gas Sendout
Chicago Air Quality Control Region
Mcf @ 1,000 Btu and 14.65 Psia
Year 1975

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	1,878,227	1,598,708	1,860,891	1,631,543	789,310	590,431	619,127	539,893	426,581	1,113,567	725,742	1,815,867
2	1,732,964	1,632,218	1,851,487	1,828,096	697,002	664,413	634,482	428,265	515,028	1,003,476	611,838	1,684,526
3	1,760,347	1,689,085	1,880,235	1,737,836	755,947	585,471	484,685	557,317	455,604	727,669	713,096	1,646,624
4	1,732,730	1,563,212	1,750,273	1,491,374	792,685	630,949	428,542	614,711	475,079	577,340	730,379	1,151,842
5	1,546,029	1,739,568	1,596,889	1,429,916	867,452	584,007	406,906	534,100	471,312	666,487	686,875	1,124,969
6	1,613,268	2,304,786	1,610,764	1,438,195	936,912	570,392	551,338	563,941	350,364	726,588	691,119	1,604,194
7	1,416,954	2,065,265	1,676,473	1,406,521	863,807	389,697	561,199	590,419	463,791	675,066	622,813	1,549,850
8	1,522,478	2,288,798	1,740,513	1,529,717	881,514	569,639	595,739	417,510	686,480	740,544	642,351	1,613,407
9	1,490,075	2,469,843	1,620,996	1,505,740	687,170	614,638	489,735	428,490	732,120	816,526	828,068	1,730,137
10	1,542,234	2,078,641	1,717,952	1,370,377	534,922	621,110	413,179	462,594	696,133	791,843	1,183,055	1,636,496
11	2,381,778	1,856,256	1,626,988	1,310,855	791,412	643,676	388,529	383,299	800,176	679,787	1,241,640	1,695,121
12	2,430,429	2,107,936	1,853,817	1,189,807	962,368	598,275	491,555	662,984	819,841	519,720	1,597,156	1,448,303
13	2,418,868	2,049,916	1,823,280	1,065,128	774,466	508,142	446,487	567,497	794,900	640,726	1,740,447	893,975
14	2,113,190	1,782,864	1,589,123	1,273,473	712,727	434,758	498,170	486,606	663,143	672,226	1,483,182	1,162,197
15	1,959,058	1,574,151	1,283,010	1,035,844	832,640	579,307	522,875	537,626	795,991	970,296	999,658	1,760,703
16	2,071,315	1,644,537	1,400,911	1,014,056	695,682	583,998	558,377	429,740	726,950	995,864	926,105	2,048,813
17	1,789,622	1,674,031	1,156,959	728,263	381,535	690,253	508,601	475,196	707,664	1,066,139	895,936	2,510,996
18	1,643,565	1,793,223	1,089,796	910,762	519,530	604,610	482,522	585,851	715,368	939,406	1,038,098	2,291,446
19	2,043,432	1,835,435	1,108,172	1,158,525	622,762	563,008	438,441	611,462	705,051	979,482	1,002,217	1,765,106
20	2,072,143	1,557,456	997,700	1,198,737	577,252	442,548	428,817	649,313	741,524	793,147	1,480,964	1,685,899
21	1,741,275	1,324,614	931,811	1,213,592	689,770	396,810	540,250	632,044	855,311	755,443	1,664,308	1,733,223
22	1,936,192	1,473,609	1,078,207	880,268	666,619	442,948	650,935	544,746	796,858	686,063	1,516,990	1,707,012
23	1,771,970	1,643,119	1,046,138	849,082	584,166	454,924	570,921	475,438	728,322	690,325	1,528,822	1,677,276
24	1,520,386	1,759,835	1,708,259	1,140,882	407,553	464,659	561,533	559,291	879,526	850,362	1,718,393	1,510,384
25	1,849,155	1,824,274	1,873,786	987,861	476,733	345,493	520,293	619,214	890,781	1,025,333	1,931,989	1,521,960
26	1,823,418	1,913,707	1,759,338	945,239	578,607	491,781	480,610	620,269	795,582	1,011,734	1,691,541	1,725,417
27	1,691,926	1,563,075	1,711,752	1,188,432	617,623	432,017	660,373	637,170	597,477	899,280	1,564,429	1,680,045
28	1,434,827	1,800,766	1,498,867	989,079	629,815	307,926	568,954	616,286	688,760	980,666	1,544,490	1,706,868
29	1,738,028		1,718,533	683,613	628,940	460,078	617,097	439,406	836,091	1,204,740	1,059,797	1,611,449
30	1,807,257		1,691,326	814,061	528,513	562,707	612,739	385,125	803,063	1,272,573	2,031,823	1,674,481
31	1,652,260		1,269,432		439,223		576,536	437,746		924,915		1,457,559
TOTAL	56,117,400	50,608,928	47,523,678	35,946,874	20,924,657	15,828,665	16,309,547	16,493,549	20,614,871	26,397,333	36,093,321	50,826,145

10-31-77

APPENDIX J

WORST-CASE NO_x CONCENTRATION DATA FOR 1975 and 1985

POWER PLANT INTERACTION GROUPS

		UTM	
Group I			
	Bethlehem Steel	488.5	4609.1
	Bailly	495.6	4606.9
	Worst Interaction Point	498.8	4605.9
Group II			
	Calumet	454.5	4618.0
	State Line	456.6	4617.3
	Mitchell	466.1	4609.6
	Worst Interaction Point	456.2	4612.9
Group III			
	Crawford	440.1	4630.8
	Fisk	445.7	4633.3
	Ridgeland	434.8	4628.9
	Worst Interaction Point	448.8	4634.7
Group IV			
	Will County	400.5	4590.4
	1/2 Way between Joliet 2 & 6 and Joliet 7 & 8	409.75	4590.95
	Worst Interaction Point	414.7	4591.2

GROUND LEVEL
NO_x CONCENTRATION AT POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP I

Study Conditions	Contributor	Concentration ($\mu g/m^3$)
Year: 1975		
Summer AM	Power Plants	2076
C-5; 70°F	CT's	0
Wind Dir = 287.2°	Other Point Sources	28
Mix Depth = 271M	Vehicles	133
R max = 10.8KM	Non-Vehicles	318
$NO_2/NO_x = \frac{1}{2}$	Total NO_x	2555
	Total NO_2	1278

GROUND LEVEL
NO_x CONCENTRATION AT POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP II

Study Conditions	Contributor	Concentration ($\mu g/m^3$)
Year: 1975		
Summer AM	Power Plants	1487
C-5; 70°F	CT's	416
Wind Dir = 288.4°	Other Point Sources	109
Mix Depth = 259M	Vehicles	161
R max = 5.4KM	Non-Vehicles	336
$NO_2/NO_x = \frac{1}{2}$	Total NO_x	2509
	Total NO_2	1255

GROUND LEVEL
NO_x CONCENTRATION AT POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP III

Study Conditions	Contributor	Concentration ($\mu g/m^3$)
Year: 1975		
Summer AM	Power Plants	1077
C-5; 70°F	CT's	910
Wind Dir = 246.0°	Other Point Sources	422
Mix Depth = 274 M	Vehicles	281
R max = 9.5KM	Non-Vehicles	499
$NO_2/NO_x = ½$	Total NO_x	3189
	Total NO_2	1595

GROUND LEVEL
NO_x CONCENTRATION OF POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP IV

Study Conditions	Contributor	Concentration ($\mu g/m^3$)
Year: 1975		
Summer AM	Power Plants	2023
C-5; 70°F	CT's	177
Wind Dir = 266.7°	Other Point Sources	40
Mix Depth = 311M	Vehicles	5
R max = 13.7KM	Non-Vehicles	31
$NO_2/NO_x = ½$	Total NO_x	2276
	Total NO_2	1138

GROUND LEVEL
NO_x CONCENTRATION AT POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP I

Study Conditions	Contributor	Concentration (µg/m³)
Year: 1985		
Summer AM	Power Plants	2076
C-5; 70°F	CT's	0
Wind Dir = 287.2°	Other Point Sources	38
Mix Depth = 271M	Vehicles	68
R max = 10.8KM	Non-Vehicles	429
NO_2/NO_x = ½	Total NO_x	2611
	Total NO_2	1301

GROUND LEVEL
NO_x CONCENTRATION AT POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP II

Study Conditions	Contributor	Concentration (µg/m³)
Year: 1985		
Summer AM	Power Plants	1448
C-5; 70°F	CT's	212
Wind Dir = 288.4°	Other Point Sources	147
Mix Depth = 259M	Vehicles	82
R max = 5.4KM	Non-Vehicles	454
NO_2/NO_x = ½	Total NO_x	2343
	Total NO_2	

GROUND LEVEL
NO_x CONCENTRATION AT POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP III

Study Conditions	Contributor	Concentration ($\mu g/m^3$)
Year: 1985		
Summer AM	Power Plants	1026
C-5; 70°F	CT's	340
Wind Dir = 246.0°	Other Point Sources	570
Mix Depth = 274M	Vehicles	143
R max = 9.5KM	Non-Vehicles	674
$NO_2/NO_x = \frac{1}{2}$	Total NO_x	2753
	Total NO_2	1377

GROUND LEVEL
NO_x CONCENTRATION AT POWER PLANT INTERACTION
WORST-CASE POINT FOR GROUP IV

Study Conditions	Contributor	Concentration ($\mu g/m^3$)
Year: 1985		
Summer AM	Power Plants	2023
C-5; 70°F	CT's	76
Wind Dir = 266.7°	Other Point Sources	54
Mix Depth = 311M	Vehicles	3
R max = 13.7KM	Non-Vehicles	42
$NO_2/NO_x = \frac{1}{2}$	Total NO_x	2198
	Total NO_2	1099

INDIVIDUAL PLANTS

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Joliet 2 and 6

Year: 1975

Study Conditions	Contributor	North	South	East	West
		Wind Direction			
Summer PM B-9; 80°F Mix Depth =800 m R max =1.7 km NO_2/NO_x = 1/2	Power Plant	490	490	490	490
	CT's	86	86	86	86
	Other Point Sources	7	4	3	13
	Vehicles	24	3	4	2
	Non-Vehicles	3	2	1	1
	Total NO_x	610	585	534	592
	Total NO_2	305	293	292	296
Summer AM C-5; 70°F Mix Depth =312 m R max =4.0 km NO_2/NO_x = 1/2	Power Plant	976	976	976	976
	CT's	219	219	219	219
	Other Point Sources	20	5	4	41
	Vehicles	70	4	10	4
	Non-Vehicles	13	4	6	4
	Total NO_x	1298	1208	1215	1244
	Total NO_2	649	604	608	622
Winter AM C-5; 20°F Mix Depth =312 m R max =4.0 km NO_2/NO_x = 1/4	Power Plant	1025	1025	1025	1025
	CT's	219	219	219	219
	Other Point Sources	20	5	4	44
	Vehicles	82	5	12	5
	Non-Vehicles	97	28	45	28
	Total NO_x	1443	1461	1305	1321
	Total NO_2	361	365	326	330

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Joliet 7

Year: 1975

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =2.6 km NO_2/NO_x = 1/2	Power Plant	247	247	247	247
	CT's	86	86	86	86
	Other Point Sources	4	1	1	8
	Vehicles	24	4	5	2
	Non-Vehicles	2	2	1	1
	Total NO_x	363	340	340	344
	Total NO_2	182	170	170	172
Summer AM C-5; 70°F Mix Depth =312 m R max =4.0 km NO_2/NO_x = 1/2	Power Plant	1020	1020	1202	1020
	CT's	219	219	219	219
	Other Point Sources	15	2	3	31
	Vehicles	68	10	11	4
	Non-Vehicles	13	6	6	4
	Total NO_x	1335	1257	1259	1278
	Total NO_2	668	629	630	639
Winter AM C-5; 20°F Mix Depth =312 m R max =4.0 km NO_2/NO_x = 1/4	Power Plant	1077	1077	1077	1077
	CT's	219	219	219	219
	Other Point Sources	15	2	3	33
	Vehicles	80	11	13	5
	Non-Vehicles	97	41	48	29
	Total NO_x	1488	1350	1360	1363
	Total NO_2	372	338	340	341

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Will County

Year: 1975

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =1.6 km NO_2/NO_x = 1/2	Power Plant	676	676	676	676
	CT's	0	0	0	0
	Other Point Sources	134	128	129	167
	Vehicles	15	4	5	2
	Non-Vehicles	1	1	1	0
	Total NO_x	826	809	811	845
	Total NO_2	413	405	406	423
Summer AM C-5; 70°F Mix Depth =282 m R max =3.6 km NO_2/NO_x = 1/2	Power Plant	1419	1419	1419	1419
	CT's	0	0	0	0
	Other Point Sources	135	165	138	146
	Vehicles	41	5	12	3
	Non-Vehicles	6	2	4	1
	Total NO_x	1601	1591	1573	1569
	Total NO_2	801	796	787	785
Winter AM C-5; 20°F Mix Depth = 282 m R max = 3.6 km NO_2/NO_x = 1/4	Power Plant	1498	1498	1498	1498
	CT's	0	0	0	0
	Other Point Sources	148	176	149	157
	Vehicles	48	6	14	4
	Non-Vehicles	43	14	29	10
	Total NO_x	1737	1694	1690	1669
	Total NO_2	434	424	423	417

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Texaco

Year: 1975

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 0.2 km NO_2/NO_x = 1/2	Power Plant	310	310	310	310
	CT's	0	0	0	0
	Other Point Sources	608	608	609	608
	Vehicles	23	12	15	6
	Non-Vehicles	3	3	3	1
	Total NO_x	944	933	937	925
	Total NO_2	472	467	469	463
Summer AM C-5; 70°F Mix Depth = 55 m R max = 0.6 km NO_2/NO_x = 1/2	Power Plant	370	370	370	370
	CT's	0	0	0	0
	Other Point Sources	1323	1337	1337	1325
	Vehicles	66	12	47	12
	Non-Vehicles	13	7	12	4
	Total NO_x	1772	1726	1766	1711
	Total NO_2	886	863	883	856
Winter AM C-5; 20°F Mix Depth = 55 m R max = 0.6 km NO_2/NO_x = 1/4	Power Plant	382	382	382	382
	CT's	0	0	0	0
	Other Point Sources	1311	1326	1326	1315
	Vehicles	77	14	55	14
	Non-Vehicles	95	48	90	33
	Total NO_x	1865	1770	1853	1744
	Total NO_2	466	443	463	436

NO_x Concentrations (μg/m^3) at Power Plant Worst Case Point for Bailly

Year: 1975

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =2.5 km NO_2/NO_x = 1/2	Power Plant	300	300	300	300
	CT's	10	10	10	10
	Other Point Sources	0	0	0	7
	Vehicles	3	5	24	35
	Non-Vehicles	0	1	5	8
	Total NO_x	313	316	339	360
	Total NO_2	157	158	170	180
Summer AM C-5; 70°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/2	Power Plant	1508	1508	1508	1508
	CT's	100	100	100	100
	Other Point Sources	0	0	0	31
	Vehicles	5	8	7	100
	Non-Vehicles	1	3	2	45
	Total NO_x	1614	1619	1617	1784
	Total NO_2	807	810	809	892
Winter AM C-5; 20°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/4	Power Plant	1592	1592	1592	1592
	CT's	100	100	100	100
	Other Point Sources	0	0	0	35
	Vehicles	5	9	8	117
	Non-Vehicles	4	10	6	215
	Total NO_x	1701	1711	1706	2059
	Total NO_2	425	428	427	515

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Bethlehem Steel

Year: 1975

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.4 km NO_2/NO_x = 1/2	Power Plant	813	813	813	813
	CT's	0	0	0	0
	Other Point Sources	0	0	0	12
	Vehicles	1	2	3	31
	Non-Vehicles	1	1	2	9
	Total NO_x	815	816	818	865
	Total NO_2	408	408	409	433
Summer AM C-5; 70°F Mix Depth = 200 m R max = 2.5 km NO_2/NO_x = 1/2	Power Plant	2623	2623	2623	2623
	CT's	0	0	0	0
	Other Point Sources	0	1	0	62
	Vehicles	2	5	7	88
	Non-Vehicles	5	4	2	46
	Total NO_x	2630	2633	2632	2819
	Total NO_2	1315	1317	1316	1410
Winter AM C-3; 20°F Mix Depth = 200m R max = 2.5km NO_2/NO_x = 1/4	Power Plant	2494	2494	2494	4819
	CT's	0	0	0	0
	Other Point Sources	0	1	0	66
	Vehicles	3	5	8	103
	Non-Vehicles	16	42	7	226
	Total NO_x	2513	2542	2509	2889
	Total NO_2	628	636	627	722

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Mitchell

Year: 1975

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.9 km NO_2/NO_x = 1/2	Power Plant	146	146	146	146
	CT's	21	21	21	21
	Other Point Sources	1	0	1	7
	Vehicles	12	8	4	36
	Non-Vehicles	3	3	1	9
	Total NO_x	183	178	173	219
	Total NO_2	92	89	87	110
Summer AM C-5; 70°F Mix Depth = 212 m R max = 2.7 km NO_2/NO_x = 1/2	Power Plant	718	718	718	718
	CT's	108	108	108	108
	Other Point Sources	3	0	4	41
	Vehicles	21	20	51	88
	Non-Vehicles	9	13	23	42
	Total NO_x	859	859	904	997
	Total NO_2	430	430	452	499
Winter AM C-5; 20°F Mix Depth = 212 m R max = 2.7 km NO_2/NO_x = 1/4	Power Plant	758	758	758	758
	CT's	108	108	108	108
	Other Point Sources	3	0	6	42
	Vehicles	24	23	59	103
	Non-Vehicles	30	42	75	227
	Total NO_x	923	931	1006	1238
	Total NO_2	231	233	252	310

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for State Line

Year: 1975

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =1.8 km NO_2/NO_x = 1/2	Power Plant	515	515	515	515
	CT's	0	0	0	0
	Other Point Sources	0	4	0	4
	Vehicles	19	29	16	47
	Non-Vehicles	1	15	9	15
	Total NO_x	535	563	540	581
	Total NO_2	268	282	270	291
Summer AM C-5; 70°F Mix Depth =262 m R max =3.3 km NO_2/NO_x = 1/2	Power Plant	1501	1501	1501	1501
	CT's	0	0	0	0
	Other Point Sources	0	17	0	4
	Vehicles	31	48	35	246
	Non-Vehicles	37	47	28	130
	Total NO_x	1569	1613	1564	1881
	Total NO_2	785	807	782	941
Winter AM C-5; 20°F Mix Depth =262 m R max =3.3 km NO_2/NO_x = 1/4	Power Plant	1584	1584	1584	1584
	CT's	0	0	0	0
	Other Point Sources	0	18	0	12
	Vehicles	36	16	29	144
	Non-Vehicles	123	34	187	320
	Total NO_x	1243	1652	1800	2060
	Total NO_2	436	413	450	515

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Calumet

Year: 1975

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =1.3 km NO_2/NO_x = 1/2	Power Plant	33	33	33	33
	CT's	149	149	149	149
	Other Point Sources	0	6	0	4
	Vehicles	19	23	14	54
	Non-Vehicles	11	10	9	13
	Total NO_x	212	221	205	253
	Total NO_2	106	111	103	127
Summer AM C-5; 70°F Mix Depth = 182 m R max = 2.2 km NO_2/NO_x = 1/2	Power Plant	103	103	103	103
	CT's	1105	1105	1105	1105
	Other Point Sources	1	0	0	3
	Vehicles	43	68	23	117
	Non-Vehicles	42	45	31	56
	Total NO_x	1294	1321	1262	1384
	Total NO_2	647	661	631	692
Winter AM C-5; 20°F Mix Depth =182 m R max =2.2 km NO_2/NO_x = 1/4	Power Plant	109	109	109	109
	CT's	1105	1105	1105	1105
	Other Point Sources	1	42	0	10
	Vehicles	50	119	30	137
	Non-Vehicles	316	420	209	320
	Total NO_x	1581	1795	1453	1681
	Total NO_2	395	449	363	420

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Ridgeland

Year: 1975

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =1.5 km NO_2/NO_x = 1/2	Power Plant	334	334	334	334
	CT's	0	0	0	0
	Other Point Sources	4	137	3	2
	Vehicles	61	32	41	38
	Non-Vehicles	7	5	7	5
	Total NO_x	406	508	385	379
	Total NO_2	203	254	193	190
Summer AM C-5; 70°F Mix Depth = 182 m R max = 2.2 km NO_2/NO_x = 1/2	Power Plant	1343	1343	1343	1343
	CT's	0	0	0	0
	Other Point Sources	26	604	22	6
	Vehicles	166	72	107	99
	Non-Vehicles	34	22	32	19
	Total NO_x	1569	2041	1504	1467
	Total NO_2	785	1021	752	734
Winter AM C-5; 20°F Mix Depth =182 m R max =2.2 km NO_2/NO_x = 1/4	Power Plant	1418	1418	1418	1418
	CT's	0	0	0	0
	Other Point Sources	27	638	26	6
	Vehicles	193	84	125	117
	Non-Vehicles	255	162	241	145
	Total NO_x	1893	2302	1810	1686
	Total NO_2	473	576	453	422

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Crawford

Year: 1975

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =1.8 km NO_2/NO_x = 1/2	Power Plant	185	185	185	185
	CT's	83	83	83	83
	Other Point Sources	0	1	5	2
	Vehicles	66	66	49	68
	Non-Vehicles	17	19	7	14
	Total NO_x	351	354	329	352
	Total NO_2	176	177	165	176
Summer AM C-5; 70°F Mix Depth =242 m R max =3.1 km NO_2/NO_x = 1/2	Power Plant	617	617	617	617
	CT's	331	331	331	331
	Other Point Sources	1	65	22	5
	Vehicles	185	155	130	163
	Non-Vehicles	72	80	32	55
	Total NO_x	1206	1248	1132	1171
	Total NO_2	603	624	566	586
Winter AM C-5; 20°F Mix Depth =242 m R max =3.1 km NO_2/NO_x = 1/4	Power Plant	651	651	651	651
	CT's	331	331	331	331
	Other Point Sources	3	56	23	5
	Vehicles	217	181	147	191
	Non-Vehicles	541	600	238	411
	Total NO_x	1743	1819	1390	1589
	Total NO_2	436	455	348	397

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Fisk

Year: 1975

Study Conditions	Contributor	Wind Direction North	Wind Direction South	Wind Direction East	Wind Direction West
Summer PM B-9; 80°F Mix Depth =800 m R max =1.4 km NO_2/NO_x = 1/2	Power Plant	383	383	383	383
	CT's	84	84	84	84
	Other Point Sources	2	8	0	74
	Vehicles	98	114	59	104
	Non-Vehicles	18	20	14	17
	Total NO_x	585	609	540	662
	Total NO_2	293	305	270	331
Summer AM C-5; 70°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/2	Power Plant	758	758	758	758
	CT's	798	798	798	798
	Other Point Sources	9	36	147	204
	Vehicles	242	312	127	269
	Non-Vehicles	67	84	58	70
	Total NO_x	1874	1988	1888	2099
	Total NO_2	937	994	944	1050
Winter AM C-5; 20°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/4	Power Plant	797	797	797	797
	CT's	798	798	798	798
	Other Point Sources	9	39	133	204
	Vehicles	283	366	148	315
	Non-Vehicles	503	627	433	524
	Total NO_x	2390	2627	2309	2638
	Total NO_2	598	657	577	660

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Winnetka

Year: 19 75

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =0.7 km NO_2/NO_x = 1/2	Power Plant	89	89	89	89
	CT's	0	0	0	0
	Other Point Sources	0	26	0	1
	Vehicles	15	79	7	30
	Non-Vehicles	2	12	1	5
	Total NO_x	106	206	97	124
	Total NO_2	53	103	49	66
Summer AM C-5; 70°F Mix Depth =122 m R max =1.5 km NO_2/NO_x = 1/2	Power Plant	197	197	197	197
	CT's	0	0	0	0
	Other Point Sources	0	130	0	1
	Vehicles	27	238	22	62
	Non-Vehicles	7	61	6	20
	Total NO_x	231	626	225	280
	Total NO_2	116	313	113	140
Winter AM C-5; 20°F Mix Depth =122 m R max =1.5 km NO_2/NO_x = 1/4	Power Plant	208	208	208	208
	CT's	0	0	0	0
	Other Point Sources	0	142	0	1
	Vehicles	32	279	25	73
	Non-Vehicles	53	461	44	151
	Total NO_x	293	1090	277	433
	Total NO_2	73	273	69	108

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Waukegan

Year: 1975

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 2.0 km NO_2/NO_x = 1/2	Power Plant	328	328	328	328
	CT's	53	53	53	53
	Other Point Sources	0	51	2	0
	Vehicles	18	67	0	18
	Non-Vehicles	2	8	1	2
	Total NO_x	401	507	384	401
	Total NO_2	201	254	192	201
Summer AM C-5; 70°F Mix Depth = 282 m R max = 3.6 km NO_2/NO_x = 1/2	Power Plant	1048	1048	1048	1048
	CT's	474	474	474	474
	Other Point Sources	0	193	9	28
	Vehicles	35	188	23	25
	Non-Vehicles	10	44	5	7
	Total NO_x	1567	1947	1559	1582
	Total NO_2	784	974	780	791
Winter AM C-5; 20°F Mix Depth = 282 m R max = 3.6 km NO_2/NO_x = 1/4	Power Plant	1106	1106	1106	1106
	CT's	474	474	474	474
	Other Point Sources	0	135	10	28
	Vehicles	40	219	27	29
	Non-Vehicles	74	326	35	54
	Total NO_x	1694	2260	1652	1691
	Total NO_2	424	565	413	423

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Collins*

Year: 1975

Study Conditions	Contributor	Wind Direction North	 South	 East	 West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 2.0 km NO_2/NO_x = 1/2	Power Plant				
	CT's				
	Other Point Sources				
	Vehicles				
	Non-Vehicles				
	Total NO_x	0	0	0	0
	Total NO_2				
Summer AM C-5; 70°F Mix Depth = 240 m R max = 3.0 km NO_2/NO_x = 1/2	Power Plant				
	CT's				
	Other Point Sources				
	Vehicles				
	Non-Vehicles				
	Total NO_x	0	0	0	0
	Total NO_2				
Winter AM C-5; 20°F Mix Depth = 240 m R max = 3.0 km NO_2/NO_x = 1/4	Power Plant				
	CT's				
	Other Point Sources				
	Vehicles				
	Non-Vehicles				
	Total NO_x	0	0	0	0
	Total NO_2				

*Plant not in service in 1975

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Joliet 2 & 6

Year: 1985

Study Conditions	Contributor	Wind Direction North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.7 km NO_2/NO_x = 1/2	Power Plant	490	490	490	490
	CT's	37	37	37	37
	Other Point Sources	9	6	5	17
	Vehicles	12	2	2	1
	Non-Vehicles	4	3	1	1
	Total NO_x	552	538	535	546
	Total NO_2	276	269	268	273
Summer AM C-5; 70°F Mix Depth = 312 m R max = 4.0 km NO_2/NO_x = 1/2	Power Plant	976	976	976	976
	CT's	93	93	93	93
	Other Point Sources	27	7	5	55
	Vehicles	36	2	5	2
	Non-Vehicles	18	5	8	5
	Total NO_x	1150	1083	1087	1131
	Total NO_2	575	542	544	566
Winter AM C-5; 20°F Mix Depth = 312m R max = 4.0km NO_2/NO_x = 1/4	Power Plant	1025	1025	1025	1025
	CT's	93	93	93	93
	Other Point Sources	27	7	5	59
	Vehicles	42	3	6	3
	Non-Vehicles	131	38	61	38
	Total NO_x	1318	1166	1190	1218
	Total NO_2	330	292	298	305

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Joliet 7

Year: 1985

		Wind Direction			
Study Conditions	**Contributor**	**North**	**South**	**East**	**West**
Summer PM B-9; 80°F Mix Depth = 800 m R max = 2.6 km NO_2/NO_x = 1/2	Power Plant	247	247	247	247
	CT's	37	37	37	37
	Other Point Sources	5	1	1	11
	Vehicles	12	2	3	1
	Non-Vehicles	3	3	1	1
	Total NO_x	304	290	289	297
	Total NO_2	152	145	145	149
Summer AM C-5; 70°F Mix Depth = 312 m R max = 4.0 km NO_2/NO_x = 1/2	Power Plant	1020	1020	1020	1020
	CT's	93	93	93	93
	Other Point Sources	20	3	4	42
	Vehicles	35	5	6	2
	Non-Vehicles	18	8	8	5
	Total NO_x	1186	1129	1131	1162
	Total NO_2	593	565	566	581
Winter AM C-5; 20°F Mix Depth = 312 m R max = 4.0 km NO_2/NO_x = 1/4	Power Plant	1077	1077	1077	1077
	CT's	93	93	93	93
	Other Point Sources	20	3	4	45
	Vehicles	41	5	7	3
	Non-Vehicles	131	55	65	39
	Total NO_x	1362	1234	1246	1257
	Total NO_2	341	309	312	314

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Will County

Year: 19 85

Study Conditions	Contributor	Wind Direction North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.6 km NO_2/NO_x = 1/2	Power Plant	676	676	676	676
	CT's	0	0	0	0
	Other Point Sources	181	233	174	226
	Vehicles	8	2	3	1
	Non-Vehicles	1	1	1	0
	Total NO_x	433	456	427	452
	Total NO_2				
Summer AM C-5; 70°F Mix Depth = 282 m R max = 3.6 km NO_2/NO_x = 1/2	Power Plant	1419	1419	1419	1419
	CT's	0	0	0	0
	Other Point Sources	182	223	186	197
	Vehicles	21	3	6	2
	Non-Vehicles	8	3	5	1
	Total NO_x	1630	1648	1616	1619
	Total NO_2	815	824	808	810
Winter AM C-5; 20°F Mix Depth = 282m R max = 3.6km NO_2/NO_x = 1/4	Power Plant	1498	1498	1498	1498
	CT's	0	0	0	0
	Other Point Sources	200	238	201	212
	Vehicles	25	3	7	2
	Non-Vehicles	58	19	39	14
	Total NO_x	1781	1758	1745	1726
	Total NO_2	445	440	436	432

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Texaco

Year: 1985

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 0.2 km NO_2/NO_x = 1/2	Power Plant	310	310	310	310
	CT's	0	0	0	0
	Other Point Sources	821	821	822	821
	Vehicles	12	6	8	3
	Non-Vehicles	4	4	4	1
	Total NO_x	1147	1141	1144	1135
	Total NO_2	574	571	572	568
Summer AM C-5; 70°F Mix Depth = 55 m R max = 0.6 km NO_2/NO_x = 1/2	Power Plant	370	370	370	370
	CT's	0	0	0	0
	Other Point Sources	1786	1805	1805	1789
	Vehicles	34	6	24	6
	Non-Vehicles	18	9	16	5
	Total NO_x	2208	2190	2215	2170
	Total NO_2	1104	1095	1108	1085
Winter AM C-5; 20°F Mix Depth = 55 m R max = 0.6 km NO_2/NO_x = 1/4	Power Plant	382	382	382	382
	CT's	0	0	0	0
	Other Point Sources	1770	1790	1790	1775
	Vehicles	39	7	38	7
	Non-Vehicles	128	65	122	45
	Total NO_x	2319	2244	2322	2209
	Total NO_2	580	561	581	552

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Bailly

Year: 1985

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth =800 m R max =2.5 km NO_2/NO_x = 1/2	Power Plant	300	300	300	300
	CT's	3	3	3	3
	Other Point Sources	0	0	0	10
	Vehicles	2	3	12	18
	Non-Vehicles	0	1	7	11
	Total NO_x	305	307	322	342
	Total NO_2	153	154	161	171
Summer AM C-5; 70°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/2	Power Plant	1508	1508	1508	1508
	CT's	34	34	34	34
	Other Point Sources	0	0	0	42
	Vehicles	3	4	4	51
	Non-Vehicles	1	4	3	61
	Total NO_x	1546	1550	1549	1696
	Total NO_2	774	776	775	849
Winter AM C-5; 20°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/4	Power Plant	1592	1592	1592	1592
	CT's	34	34	34	34
	Other Point Sources	0	0	0	47
	Vehicles	3	5	4	60
	Non-Vehicles	5	14	8	290
	Total NO_x	1634	1645	1638	2023
	Total NO_2	409	412	410	506

NO$_x$ Concentrations (μg/m^3) at Power Plant Worst Case Point for Bethlehem Steel

Year: 1985

Study Conditions	Contributor	Wind Direction North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800m R max = 1.4km NO$_2$/NO$_x$ = 1/2	Power Plant	813	813	813	813
	CT's	0	0	0	0
	Other Point Sources	0	0	0	16
	Vehicles	1	1	2	16
	Non-Vehicles	1	1	3	12
	Total NO$_x$	815	815	818	857
	Total NO$_2$	408	408	409	429
Summer AM C-5; 70°F Mix Depth = 200 m R max = 2.5 km NO$_2$/NO$_x$ = 1/2	Power Plant	2363	2363	2363	2363
	CT's	0	0	0	0
	Other Point Sources	0	1	0	84
	Vehicles	1	3	4	45
	Non-Vehicles	7	5	3	62
	Total NO$_x$	2371	2372	2370	2554
	Total NO$_2$	1186	1186	1185	1277
Winter AM C-3; 20°F Mix Depth = 200 m R max = 2.5 km NO$_2$/NO$_x$ = 1/4	Power Plant	2494	2494	2494	2494
	CT's	0	0	0	0
	Other Point Sources	0	1	0	89
	Vehicles	2	3	4	53
	Non-Vehicles	22	57	9	305
	Total NO$_x$	2518	2555	2507	2941
	Total NO$_2$	630	639	627	735

NO$_x$ Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Mitchell

Year: 1985

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.9 km NO_2/NO_x = 1/2	Power Plant	146	146	146	146
	CT's	14	14	14	14
	Other Point Sources	2	0	1	10
	Vehicles	6	4	2	18
	Non-Vehicles	4	4	1	12
	Total NO$_x$	172	168	177	200
	Total NO_2	86	84	89	100
Summer AM C-5; 70°F Mix Depth = 212 m R max = 2.7 km NO_2/NO_x = 1/2	Power Plant	718	718	718	718
	CT's	67	67	67	67
	Other Point Sources	4	0	6	56
	Vehicles	11	10	26	45
	Non-Vehicles	12	18	31	57
	Total NO$_x$	812	813	848	943
	Total NO_2	406	407	424	472
Winter AM C-5; 20°F Mix Depth = 212 m R max = 2.7 km NO_2/NO_x = 1/4	Power Plant	758	758	758	758
	CT's	67	67	67	67
	Other Point Sources	4	0	8	57
	Vehicles	12	12	30	53
	Non-Vehicles	41	57	101	306
	Total NO$_x$	882	894	964	1241
	Total NO_2	221	224	241	310

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for State Line

Year: 1985

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.8 km NO_2/NO_x = 1/2	Power Plant	515	515	515	515
	CT's	0	0	0	0
	Other Point Sources	0	5	0	5
	Vehicles	10	15	8	24
	Non-Vehicles	1	20	12	20
	Total NO_x	526	555	535	564
	Total NO_2	263	278	268	282
Summer AM C-5; 70°F Mix Depth = 262 m R max = 3.3 km NO_2/NO_x = 1/2	Power Plant	1501	1501	1501	1501
	CT's	0	0	0	0
	Other Point Sources	0	23	0	5
	Vehicles	16	25	18	125
	Non-Vehicles	50	63	38	176
	Total NO_x	1567	1612	1557	1807
	Total NO_2	784	806	779	904
Winter AM C-5; 20°F Mix Depth = 262 m R max = 3.3 km NO_2/NO_x = 1/4	Power Plant	1584	1584	1584	1584
	CT's	0	0	0	0
	Other Point Sources	0	25	0	16
	Vehicles	18	8	15	73
	Non-Vehicles	166	46	252	432
	Total NO_x	1768	1663	1851	2105
	Total NO_2	442	416	463	526

NO$_x$ Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Calumet*

Year: 19 85

Study Conditions	Contributor	Wind Direction North	 South	 East	 West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.3 km NO$_2$/NO$_x$ = 1/2	Power Plant				
	CT's				
	Other Point Sources				
	Vehicles				
	Non-Vehicles				
	Total NO$_x$	0	0	0	0
	Total NO$_2$				
Summer AM C-5; 70°F Mix Depth = 182m R max = 2.2km NO$_2$/NO$_x$ = 1/2	Power Plant				
	CT's				
	Other Point Sources				
	Vehicles				
	Non-Vehicles				
	Total NO$_x$	0	0	0	0
	Total NO$_2$				
Winter AM C-5; 20°F Mix Depth = 182 m R max = 2.2 km NO$_2$/NO$_x$ = 1/4	Power Plant				
	CT's				
	Other Point Sources				
	Vehicles				
	Non-Vehicles				
	Total NO$_x$	0	0	0	0
	Total NO$_2$				

*Plant Retired Prior to 1985

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Ridgeland

Year: 1985

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.5 km NO_2/NO_x = 1/2	Power Plant	334	334	334	334
	CT's	0	0	0	0
	Other Point Sources	5	185	5	3
	Vehicles	31	16	21	19
	Non-Vehicles	9	7	9	7
	Total NO_x	379	542	369	363
	Total NO_2	190	271	185	182
Summer AM C-5; 70°F Mix Depth = 182 m R max = 2.2 km NO_2/NO_x = 1/2	Power Plant	1343	1343	1343	1343
	CT's	0	0	0	0
	Other Point Sources	36	815	29	8
	Vehicles	85	37	55	51
	Non-Vehicles	46	30	43	26
	Total NO_x	1510	2225	1470	1428
	Total NO_2	755	1113	735	714
Winter AM C-5; 20°F Mix Depth = 182 m R max = 2.2 km NO_2/NO_x = 1/4	Power Plant	1418	1418	1418	1418
	CT's	0	0	0	0
	Other Point Sources	37	861	34	8
	Vehicles	98	43	64	60
	Non-Vehicles	344	219	325	196
	Total NO_x	1897	2541	1841	1682
	Total NO_2	474	635	460	421

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Crawford

Year: 1985

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.8 km NO_2/NO_x = 1/2	Power Plant	146	146	146	146
	CT's	53	53	53	53
	Other Point Sources	1	1	7	2
	Vehicles	34	34	25	35
	Non-Vehicles	23	26	9	19
	Total NO_x	257	260	240	255
	Total NO_2	129	130	120	128
Summer AM C-5; 70°F Mix Depth = 242 m R max = 3.1 km NO_2/NO_x = 1/2	Power Plant	485	485	485	485
	CT's	208	208	208	208
	Other Point Sources	2	88	30	7
	Vehicles	94	79	66	83
	Non-Vehicles	97	108	43	74
	Total NO_x	886	968	832	857
	Total NO_2	443	484	416	430
Winter AM C-5; 20°F Mix Depth = 242 m R max = 3.1 km NO_2/NO_x = 1/4	Power Plant	512	512	512	512
	CT's	208	208	208	208
	Other Point Sources	4	75	41	7
	Vehicles	111	92	75	97
	Non-Vehicles	730	810	321	555
	Total NO_x	1565	1697	1157	1379
	Total NO_2	391	424	289	345

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Fisk

Year: 1985

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 1.4 km NO_2/NO_x = 1/2	Power Plant	383	383	383	383
	CT's	28	28	28	28
	Other Point Sources	2	10	0	100
	Vehicles	50	58	30	53
	Non-Vehicles	24	27	19	23
	Total NO_x	487	506	460	587
	Total NO_2	244	253	230	294
Summer AM C-5; 70°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/2	Power Plant	758	758	758	758
	CT's	266	266	266	266
	Other Point Sources	12	48	199	275
	Vehicles	123	159	65	137
	Non-Vehicles	90	113	78	95
	Total NO_x	1249	1344	1366	1531
	Total NO_2	625	672	683	766
Winter AM C-5; 20°F Mix Depth = 272 m R max = 3.5 km NO_2/NO_x = 1/4	Power Plant	797	797	797	797
	CT's	266	266	266	266
	Other Point Sources	13	52	180	275
	Vehicles	144	187	75	161
	Non-Vehicles	679	846	585	707
	Total NO_x	1899	2148	1903	2206
	Total NO_2	475	537	476	562

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Winnetka

Year: 19 85

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 0.7 km NO_2/NO_x = 1/2	Power Plant	89	89	89	89
	CT's	0	0	0	0
	Other Point Sources	0	35	0	1
	Vehicles	8	40	4	15
	Non-Vehicles	3	16	1	7
	Total NO_x	100	180	94	112
	Total NO_2	50	90	47	56
Summer AM C-5; 70°F Mix Depth = 122 m R max = 1.5 km NO_2/NO_x = 1/2	Power Plant	197	197	197	197
	CT's	0	0	0	0
	Other Point Sources	0	176	0	2
	Vehicles	14	121	11	32
	Non-Vehicles	9	82	8	27
	Total NO_x	220	576	216	258
	Total NO_2	110	288	108	129
Winter AM C-5; 20°F Mix Depth = 122 m R max = 1.5 km NO_2/NO_x = 1/4	Power Plant	208	208	208	208
	CT's	0	0	0	0
	Other Point Sources	0	192	0	2
	Vehicles	16	142	13	37
	Non-Vehicles	72	622	59	204
	Total NO_x	296	1164	280	451
	Total NO_2	74	291	70	113

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Waukegan

Year: 1985

		Wind Direction			
Study Conditions	Contributor	North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 2.0 km NO_2/NO_x = 1/2	Power Plant	328	328	328	328
	CT's	142	142	142	142
	Other Point Sources	0	68	3	0
	Vehicles	9	34	0	9
	Non-Vehicles	3	11	1	3
	Total NO_x	354	455	346	354
	Total NO_2	177	228	173	177
Summer AM C-5; 70°F Mix Depth = 282 m R max = 3.6 km NO_2/NO_x = 1/2	Power Plant	1048	1048	1048	1048
	CT's	124	124	124	124
	Other Point Sources	0	261	12	38
	Vehicles	18	96	12	13
	Non-Vehicles	14	59	7	7
	Total NO_x	1204	1588	1203	1232
	Total NO_2	602	794	602	616
Winter AM C-5; 20°F Mix Depth = 282 m R max = 3.6 km NO_2/NO_x = 1/4	Power Plant	1106	1106	1106	1106
	CT's	124	124	124	124
	Other Point Sources	0	182	13	38
	Vehicles	20	112	14	15
	Non-Vehicles	100	440	47	73
	Total NO_x	1350	1964	1304	1356
	Total NO_2	338	491	326	339

NO_x Concentrations ($\mu g/m^3$) at Power Plant Worst Case Point for Collins

Year: 19 85

Study Conditions	Contributor	Wind Direction			
		North	South	East	West
Summer PM B-9; 80°F Mix Depth = 800 m R max = 2.0 km NO_2/NO_x = 1/2	Power Plant	217	217	217	217
	CT's	0	0	0	0
	Other Point Sources	1	0	0	0
	Vehicles	6	1	1	1
	Non-Vehicles	1	0	0	0
	Total NO_x	225	218	218	218
	Total NO_2	113	109	109	109
Summer AM C-5; 70°F Mix Depth = 240 m R max = 3.0 km NO_2/NO_x = 1/2	Power Plant	892	892	892	892
	CT's	0	0	0	0
	Other Point Sources	5	0	1	0
	Vehicles	16	1	3	3
	Non-Vehicles	4	1	1	1
	Total NO_x	917	894	897	896
	Total NO_2	459	447	449	448
Winter AM C-5; 20°F Mix Depth = 240 m R max = 3.0 km NO_2/NO_x = 1/4	Power Plant	942	942	942	942
	CT's	0	0	0	0
	Other Point Sources	5	0	1	0
	Vehicles	18	2	3	3
	Non-Vehicles	32	5	12	9
	Total NO_x	997	949	958	954
	Total NO_2	249	237	240	239